BETTER TO BE FORESIGHTED THAN MYOPIC: A FORESIGHT FRAMEWORK FOR AGRICULTURE, FOOD SECURITY, AND R&D IN LATIN AMERICA AND THE CARIBBEAN.

Eugenio Díaz-Bonilla*, Eugenia Saini**, Bernardo Creamer***, and Guy Henry****[1]

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[1]*CIAT/IFPRI; **IICA; ***CIAT/IFPRI; and ****CIAT/CIRAD

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Glossary

CIAT: International Center for Tropical Agriculture

CGIAR: Consultative Group on International Agricultural Research

GCARD: Global Conference Agricultural Research for Development

GFAR: Global Forum on Agricultural Research

IICA: Inter American Institute for Cooperation on Agriculture

IFPRI: International Food Policy Research Institute

IADB: Inter American Development Bank

USDA: U. S. Department of Agriculture

FAO: Food and Agriculture Organization

IPCC: Intergovernmental Panel on Climate Change

MA: Millennium Ecosystem Assessment

LAC: Latin America and the Caribbean

R&D: Research and Development

1 INTRODUCTION

In preparation for the 2010 Global Conference on Agricultural Research for Development (GCARD), the Forum for the Americas on Agricultural Research and Technology Development (FORAGRO)[2] organized a consultation to define priorities for agricultural research and development (R&D) in Latin America and the Caribbean (LAC).[3] In light of global developments since then, several organizations[4] have joined forces to develop a foresight framework that can support strategic planning and decision making related to agricultural R&D policies and investments in LAC, with the aim of strengthening food security at the local, national, and global levels and fostering sustainable development to generate income and employment in the region, particularly for the poor and vulnerable.

As a first step, a workshop was held at the Inter-American Development Bank (IDB) in Washington, D.C., during March 2012, to analyze global trends and scenarios. Then, in October 2012, the implications for agricultural R&D were explored at an expert consultation organized at the International Center for Tropical Agriculture (CIAT) in Colombia. The discussions in those events are a substantial input for this document, which in turn is expected to help the process of developing a framework (or frameworks) for foresight exercises related to agriculture in Latin America and the Caribbean (LAC) to

[2] FORAGRO is an institutional mechanism for the Americas to facilitate discussion and help define a regional agenda for agricultural technology. It has as members different national, regional and international institutions operating in the Americas. The Inter-American Institute for Cooperation in Agriculture (IICA) acts as Secretariat (see a full description in http://www.iica.int/foragro/documentos/FORAGRO_ingles.pdf)

[3] See for instance Salles et al, 2009, Trigo, 2009, Carriquiry and Otero, 2009, and FORAGRO, 2010

[4] Participants in the LAC Foresight Study included the following persons and organizations, in alphabetical order: Flavio Avila (Brazilian Agricultural Research Corporation, EMBRAPA); Carol Brookins (Public Capital Advisors LLC); , Fernando Chaparro, University of Rosario and Colombian Administrative Department of Science, Technology and Innovation (COLCIENCIAS); Bernardo Creamer (International Center of Tropical Agriculture, CIAT, and International Food Policy Research Institute (IFPRI)); Uri Dadush (Carnegie Endowment for International Peace); Eugenio Díaz-Bonilla (CIAT/IFPRI); Ruben Echeverría (CIAT); Ramón Espinasa (Inter-American Development Bank, IDB); Keith Fuglie (United States Department of Agriculture, USDA); Elcio Guimarães, (CIAT); David Hatch (Inter-American Institute for Cooperation on Agriculture, IICA); Priscila Henríquez (IICA); Guy Henry (CIAT and French Agricultural Research Centre for International Development, CIRAD); Andy Jarvis (CIAT); Marie de Lattre-Gasquet (CIRAD); Mark Lundy (CIAT); Phillip Pardey (University of Minnesota); Ruben Patrouilleau (National Institute of Agricultural Technology, INTA-Argentina); Adrián Rodríguez (Economic Commission for Latin America and the Caribbean, ECLAC); Mark Rosegrant (IFPRI); Eugenia Saini, IICA/Regional Fund for Agricultural Technology (Fontagro), José Luis Samaniego (ECLAC); Carlos Santana (EMBRAPA); Hans Timmer (World Bank); Joe Tohme (CIAT); Rafael Trejos (IICA); Eduardo Trigo (CEO Group, Economics and Organization Consultants); Ronald Trostle (USDA); Dominique van de Mensbrugghe (Food and Agriculture Organization of the United Nations, FAO); Walter Vergara (IDB); Steven Zahniser (USDA).

provide guidance for agricultural R&D, policy research, and innovation and knowledge transfer in the region. A policy brief summarizing the first version of this document was presented at GCARD 2012.[5]

Foresight studies involve a wide variety of methods (see Section 3), of which scenario building is among the most common. The study described here centers mainly on scenario building, while recognizing that other methods are needed as well. It mostly uses a 2030 horizon but also takes into account some shorter-term issues. The document is organized in seven sections, including this Introduction (Section 1). The second section discusses how the issue of foresight is approached in some CGIAR and CGARD documents. Section 3 revises foresight definitions and methods. Section 4 presents a brief characterization of LAC's agriculture and food developments over the last half a century, as a background to the identification of drivers and trends. Section 5 focuses on different strategic dimensions and potential trends, related to macroeconomics, demography, poverty, climate change, and technology, among other things, whose evolution and combinations define future scenarios. Section 6 proposes several potential scenarios, which, although with different likelihoods of becoming reality, cover a broad range of possible futures. Section 7 finalizes with some conclusions related to LAC agriculture and R&D strategic issues.

While recognizing the heterogeneity of agriculture in LAC, this study addresses the region as a whole, with the aim of presenting a general framework that could later be used for a more detailed analysis in particular subregions, countries, agro-ecological zones, value-chains, or products.

2 FORESIGHT IN CGIAR AND GCARD DOCUMENTATION

2.1 CGIAR

The CGIAR strategy (CGIAR, 2010a) refers to foresight only in the context of the GCARD process. Rather, the CGIAR strategy emphasizes a management by results framework, "under which a coherent framework for strategic planning, management, and communications based on continuous learning and accountability will be implemented. The implementation of this framework requires, as a first step, the identification of development outcomes to which research activities will contribute. The CGIAR has derived, from the MDGs and the CGIAR Vision, four system level outcomes that will serve as the focal point of all CGIAR research activities." Those four system level outcomes (SLOs) are defined as: a) reducing rural poverty, b) improving food security, c) improving nutrition and health, and d) sustainable management of natural resources (CGIAR 2010a).

[5] The policy brief can be found in http://www.ciat.cgiar.org/work/latinamerica/Documents/synthesis_foresight.pdf. More information about GCARD 2 can be found at http://www.egfar.org/gcard-2012.

Therefore, the strategy focuses on planning and development results, which are by necessity related to some view of the future, but without emphasizing the idea of foresight studies. Subsequent CGIAR documents have been increasingly using the notion of foresight as a tool for planning, decision-making, and priority setting. This is the case of several CGIAR Research Projects (CRPs). For instance, the idea of foresight appears in greater detail in the CRP2 (Policies, Institutions, & Markets to Strengthen Food Security and Incomes for the Rural Poor) (CGIAR, 2010b). In its "Theme 1: Effective Policies and Strategic Investments," the document identifies a specific Subtheme devoted to Foresight and Strategic Scenarios, which focus "on designing scenarios reflecting emerging challenges, modeling the consequences of these scenarios, and using the outputs of the modeling to inform policy research, thereby improving existing agricultural policy and investment decisions." The work on Foresight and Strategic Scenarios is "designed to capture how global drivers and scenarios influence countries throughout the world while capturing the interconnections of agricultural markets and the global externalities of climate change." It was indicated that the Foresight program will work closely with the GCARD process (see below). The work under the foresight category would include ex ante analysis of the impacts of policy research using simulation and scenarios analysis, such as those carried with the IMPACT model over long-term scenarios (for instance, 2050). Usually, those scenarios consider broader investment topics rather than specific agricultural technologies or crop simulations, but in Nelson et al (2010) there are yield improvement scenarios for corn, wheat and cassava; and in the CRP2 is argued that "the analysis allows for assessment of highly disaggregated and spatially explicit subnational productivity and natural resource impacts of drivers of global change."

CRP7 (Climate Change, Agriculture and Food Security) (CGIAR, 2010c) also considers foresight analysis and *ex ante* impact assessments to drive budget allocations, as part of the Research Theme 4 -Objectives 1, 2 and 3-, in the context of climate change issues (p.25). In the section on "Foresight, priority setting and impact assessment" (p.30-33) it is stated that "targeting food security, poverty reduction and sustainable natural resource management interventions that are robust in the face of a changing and uncertain climate requires a strong *ex-ante* analytical capacity to diagnose points of vulnerability and assess the impacts and trade-offs between socioeconomic and environmental goals associated with alternative strategies. Major components of this CRP will involve foresight studies, vulnerability assessment and ex ante impact assessment." In particular Objective 1 in Theme 4 is scenario development, working with a range of stakeholders in order to explore "possible scenarios of the future, potential options for influencing trajectories of change, and opportunities for achieving outcomes and impact. A major focus will be at the regional scale, but global and local work will also be conducted." CRP7 considers different methodologies including qualitative scenarios and quantitative analyses, and other modeling tools to inform priority setting. It also refers to the use of vulnerability assessment through

"novel techniques to capture elements of adaptive capacity in communities, and thus earmark areas where specific adaptation and mitigation options may be feasible." Finally, other tools, such as the Delphi technique, are also mentioned to be used with regional and local partners in setting priorities in CRP7 and helping to determine the allocation of funds to Themes and Objectives.

2.2 GLOBAL CONFERENCE ON AGRICULTURAL RESEARCH FOR DEVELOPMENT (GCARD)

The GCARD Road Map tries to integrate Agricultural Research for Development (AR4D) on a global scale, in order to build more cohesive systems so that agricultural knowledge, science and technology can play a full role in removing poverty, hunger and malnutrition from the world, meeting "both the pressing nutrition and income needs of the rural poor and the food demand of increasingly urbanized populations, while ensuring the sustainability of production and food systems." (GFAR/GCARD/CGIAR, 2010). Among the specific development impacts to the achieved by AR4D systems, the GCARD Road Map mentions "sustainable intensification, better access to safe, nutritious food by vulnerable communities, increasing agricultural incomes through value-adding post-harvest management and creating entrepreneurial opportunities for resource-poor smallholder farmers and producers."According to the Road Map the six essential characteristics of well-functioning AR4D systems are as follows:

1. Inclusively defines key AR4D priorities and actions, driven by evolving national, regional and global development
2. Invests in ensuring equitable partnership and accountability among all stakeholders of agricultural innovation and developmental change
3. Actively achieves increased investments in human, institutional and financial resources for AR4D systems to meet demands in development
4. Develops required institutional capacities for generation, access and effective use of agricultural knowledge in development
5. Effectively coordinates linkages relating agricultural innovation to development programs and policies
6. Demonstrates its value and gains recognition by society through involvement of stakeholders in effective demonstration and reporting of outcomes

The issue of foresight appears mentioned in the context of the first characteristic: the definition, through inclusive means, of key AR4D priorities and actions. The GCARD 2010 process has identified key AR4D themes and actions on a global scale, based on a multi stakeholder review and consultation, which included Governments, Agricultural Research Fora in each region of the world, the CGIAR and

other international organizations. Those global priorities are supposed to be then considered at the national and regional contexts and "mapped against the incidence of poverty, food and nutritional insecurity, environmental degradation," and the existence of potential partnerships, in order to determine "where interventions can bring greatest benefits and impacts. "To do that the GCARD Road Map considers that foresight is essential to prioritize the development needs and future priorities, to recognize the benefits and trade-offs among potential policy options, and to generate a clear view of emerging new challenges. Those foresight exercises should be done through multiple "lenses," considering that each approach "may resolve only part of the story, but together they can produce collective best-bets on future needs," integrating "a range of perspectives on key issues, making use of the best available data and interpretations from different sources and directly integrating the diverse views of farmers and other stakeholders on specific problems."

The GCARD Road Map considers that those foresight exercises, which are part of strategic planning and prioritization on AR4D, must be done by national institutions and regional and sub-regional fora, as well as international institutions. Such improved foresight would "mobilize expert analyses within countries to analyze specific themes of concern and bring together, via GFAR and the regional Fora and on a coherent and regular basis, the diverse national and international initiatives" to examine relevant development scenarios through different lenses and learn from the outcomes of the different models and perspectives employed. At the same time "wide stakeholder consultation will be mobilized through national and regional fora, to 'ground-truth' the realities and impacts of trends among poor rural communities."

Regarding foresight exercises the GCARD Road Map establishes as outcome the existence of "future agricultural scenarios projected by multi-stakeholder cross-referenced analyses, to better identify new knowledge needs and shape research required;" and as milestones "i) Foresight academy consortia established to address future needs in national and regional contexts. ii) Coordinated foresight actions established at international level to stimulate and integrate diverse analyses of key issues and their projections."

2.3 CONCLUSION

The GCARD process but also CGIAR institutions have identified the need to conduct foresight exercises as part of the strategic planning and decision making process related to agricultural technology. The aim of this document is precisely to contribute to the foresight exercises mentioned in the CGIAR and GCARD documents. It focuses on LAC, also in line with the need, mentioned in CGIAR and GCARD documents, to combine global exercises with those, like this one, which is regional in nature.

But before getting deeper into the exercise it seems prudent to ask what is the operational meaning of "foresight", and what are the methods utilized. These questions are briefly reviewed in the next section.

3 FORESIGHT: DEFINITIONS, METHODS, PROCESSES AND OUTPUTS

The first thing to recognize is the widespread use and popularity of the term "foresight studies" (and variations of the same idea) in reference to what seems a large variety of approaches and activities increasingly undertaken by many governments and organizations as part of their decision-making processes. For instance, it was noted that "With the success of a number of foresight exercises, it has become common for the term 'foresight' to be used to cover all sorts of activities. There has been much re-branding of technology watch, environmental scanning, forecasting and similar activities as foresight" (the European Foundation for the Improvement of Living and Working Conditions (2003); p 20).[6] Because it appears as a field in ebullient activity,[7] it would be impossible to try to provide here a detailed survey of the different strands of work covered under "foresight studies." In this section we have a more modest focus: to present a brief summary of some definitions and approaches, as a background for the rest of the paper.

3.1 HISTORY, DEFINITIONS AND CHARACTERISTICS

Human beings have always tried to anticipate what the future may bring to be better prepared and/or to try to influence the final outcomes. More systematic thinking about forward-looking planning and decision making emerged only after WWII, in the context of war game scenarios for the Cold War during the 1960s, and in the case of some energy companies (Kahn and Weiner, 1967). These approaches were based more on qualitative narratives. In the early 1970s quantitative approaches began to be

[6] Certainly, the popularity of the term may also be related to its positive connotations: for instance, the Merriam-Webster Thesaurus presents as synonyms to "foresight" and related words positive terms such as "foreknowledge," "prescience," "omniscience," "farsightedness," "providence," "vision," "precaution," "discernment," "discretion," "insight," "perceptiveness," "prudence," "sagaciousness," "sapience," and "wisdom." The antonyms are equally telling: "improvidence," "myopia," and "shortsightedness." Considering that most people would like to be "farsighted" rather than "myopic," or "prudent" instead of "improvident," it would be easy to understand the proliferation of what are called "foresight" activities simply on this account.

[7] The list of publications on this topic is very long, including multiple web sites (see the list compiled by the International Futures Program of the OECD in http://www.oecd.org/document/7/0,3746,en_2649_33707_20600455_1_1_1_1,00.html), several manuals (e.g. UNIDO, 2005 volume 1 and 2; and European Foundation for the Improvement of Living and Working Conditions, 2003; in Spanish there is the Manual from the Instituto Latinoamericano y del Caribe de Planificación Económica y Social, ILPES, by Medina and Ortegón 2006; and also journals (e.g. Technological Forecasting and Social Change, An International Journal, by Elsevier; World Futures, by Routledge, and so on).

developed with the work by Forrester (1971) and Meadows et al. (1972).[8] LAC has a large tradition of development planning (Leiva, 2012), which has been, by necessity, a forward-looking exercise. In most of those approaches, basically related to policy decision-making of some type, there has always been a consideration of the future state (or states) both of the unit that was the basis for the planning exercises (such as a country, organization, or firm) and of the context or environment where that unit will be operating. As noted by Cuervo (2012), the motivation for foresight work has been very similar to economic and social planning in general: "to generate general-interest goals and common visions … as well as mobilizing appropriate resources to attain them." However, Cuervo (2012) notes that LAC prospective (or foresight), which was born a couple of decades later than the original planning efforts, does not seem to recognize the common origin as one of the several approaches to planning, even though both, planning and foresight, emerge from the same concerns, face common challenges (such as conciliating diverse interests to build general-interest goals, the need to use different types of knowledge, and the coordination of diverse institutions and organizations), and may suffer from similar shortcomings (such as weaknesses in monitoring and evaluation which should be an integral part of the exercise).[9]

In fact, planning/policy decision-making, on the one hand, and foresight studies, on the other, are two parts of a whole: simplifying a more complex issue it could be argued that planning and policy development exercises emphasize what to do to attain some objectives in a potential future state, while foresight studies highlight the constraints and opportunities that such potential future state and the evolution towards it may impose on what needs to be done to attain the desired objectives.

Notwithstanding those common roots and complementarities, foresight exercises have evolved as separate from planning, and usually they are considered something different not only from strategic planning, but also from other related activities such as forecasting and policy development. However, as noted, foresight can and should complement and enhance the effectiveness of planning and policy-making activities.

A general definition of foresight as currently understood is provided by the FORLEARN Program of the Institute for Prospective Technological Studies (IPTS) (one of the seven scientific institutes of the European Commission's Joint Research Centre): "Foresight is a systematic, participatory, future-intelligence-gathering and medium-to-long-term vision-building process aimed at enabling present-day decisions and mobilizing joint actions"(Joint Research Centre/Institute for Prospective Technological Studies (IPTS) FORLEARN Program). In particular technological foresight has been defined as "the

[8] For a brief history of foresight studies see Raskin et al (2005) Chapter 2 Millennium Ecosystem Assessment.

[9] The origin of LAC prospective/foresight is usually linked to the so-called Bariloche Model (see Herrera et al, 1976), which was unique in its time for having an explicit normative purpose (i.e. defining a desired future and exploring pathways to get there) (see Raskin et al (2005), and Cuervo 2012).

process involved in systematically attempting to look into the longer-term future of science, technology, the economy and society with the aim of identifying the areas of strategic research and the emerging generic technologies likely to yield the greatest economic and social benefits" (Ben Martin, 1996). Therefore, foresight exercises appear to have several characteristics (UNIDO, 2005; European Foundation for the Improvement of Living and Working Conditions, 2003; FORLEARN Program, 2012):

- They include a systematic look at the future to a) try to understand the potential evolution of the variables or processes of interest ("anticipatory intelligence'), and/or b) developing strategic visions of the future. It is systematic in that it uses structured approaches, which may be qualitative, quantitative, or a combination, to focus on the economic, social, technological, political, and other developments of interest and to determine the challenges they pose and opportunities they offer.
- They are participatory, trying to involve relevant actors in a substantive dialogue. In this regard, the participants in foresight exercises may go beyond a narrow set of experts, and try to bring together affected parties, agents of change and sources of knowledge. In that sense one of the outputs highlighted by foresight studies is the establishment of networks among the participants concerned about a topic and the related long-term challenges, allowing them to share knowledge resources, and to understand the values, strategic orientations, and visions of the future of others. Networks also serve to disseminate the results of the exercise and receive feedback.
- They are multidisciplinary, considering that the complexity of the issues involved requires perspectives from different disciplines and approaches.
- They are oriented to taking action, to anticipate, adapt to, or try to change the envisioned future. Usually foresight approaches consider that the future is indeterminate, depending on current underlying driving forces and trends and new developments and forces, but also, and more relevant for the point emphasized here, on the actions taken today and in following time periods by the agents involved. In that sense, foresight exercises should be, as argued before, complementary to strategic planning and policy decision-making, to the extent that one important output of the foresight exercise (such as scenarios, lists of priority issues, and so on) should help current decision-making.

3.2 METHODS AND APPROACHES

Foresight methods can be categorized along several dimensions (UNIDO, 2005). One such distinction is between exercises that start from the present and explore the future, and those that start from the future (usually a desirable one, but not always) and then try to determine the paths to get there (if it is

a desirable future) or to avoid it (if not). Sometimes these two approaches are called "exploratory" and "normative," respectively, but in fact both may involve exploration, and include values and norms. Other way of referring to this distinction is "forward casting" and "back-casting," respectively. Different analysis may call for one approach or the other, although sometimes a combination of both may be required. The value of "normative" approaches will depend on whether there is enough commonality in visions about what is a desirable future (European Foundation for the Improvement of Living and Working Conditions (2003), UNIDO, 2005).

A second distinction is between quantitative methods using numerical variables and indicators to characterize events, and qualitative methods, which are applied when there is no data on variables otherwise quantifiable, or, and more fundamentally, when it is difficult to define and quantify the variables of interest. Certainly, when the topic analyzed can be represented by quantifiable variables and relations, it is always better the first approach. But in analyzing complex socio-economic-physical-biological systems, there may not be adequate data, and a qualitative approach, which is also more open to creative thinking and brainstorming, may be the right approach in some cases. Both methods can also be mixed, depending on the type of issues analyzed (European Foundation for the Improvement of Living and Working Conditions (2003), UNIDO, 2005).

A third distinction is between a) approaches that utilize known data and relations and use them to project the future (which usually are also less participatory and interactive than other foresight exercises), and b) those that depend on the views of experts who are asked about their opinion and the evidence that supports their pronouncements (such as in Delphi methods, scenario workshops, and cross-impact analysis) (UNIDO, 2005). Again, in many cases a combination of both methods may be needed[10]. Whatever the dimensions utilized to characterize foresight exercises, there has been a steady increase in foresight methods. For instance, UNIDO (2005) identifies several foresight methods (see also European Foundation for the Improvement of Living and Working Conditions, 2003) that cover some of the main approaches used in foresight studies over the last decade, and classifies them in four groups (Table 1).

Table 1. Foresight Methods.

Group	Method
Identifying Issues	*Environmental Scanning, *SWOT (strengths, weaknesses, opportunities, and threats) Analysis *Issue Surveys
Extrapolative Approaches	*Trend Extrapolation

[10] It is obvious to note that each approach has its advocates: UNIDO (2005) recognizes "a division between "forecasters" who favor quantitative/exploratory methods, and "futurists" who prefer the qualitative/normative. Advocates of one approach may be dismissive of the other despite the fact that there is a considerable overlap between them." (UNIDO, 2005).

	*Simulation Modeling *"Genius" Forecasting *Delphi
Creative Approaches	*Brainstorming *Expert Panels *Cross-Impact Analysis *Scenarios
Prioritization	*Critical (and Key) Technologies *Technology Road-mapping

From: UNIDO 2005 using Miles and Keenan, (2003).

Although each method appears as a separate one, with a specific name, they are usually flexible in their application and may overlap with others: for instance simulation modeling can be utilized for scenario building (see below the discussion on scenarios). In Annex 1 there is a brief description of several methods presented in UNIDO (2005).

3.3 WHEN AND HOW TO CONDUCT A FORESIGHT EXERCISE

The first issue is to determine whether a foresight exercise is the best approach. It may not be the best alternative if there is no possibility of acting on the results because of the nature of the problem or because there is no interest in acting by the main implementing organizations, or if key stakeholders cannot be actively engaged with the project, or there is not a clear agreement on the scope and focus of the exercise; and adequate resources to complete the project are not available (FORLEARN Program, 2012). Also, there may be decisions that may not require elaborate foresight exercises, given the scale and focus of the issue considered. If it is decided that a foresight exercise is needed, then it is further necessary to consider, within the range of foresight methods, which one may be the more adequate for the issue at hand. If those, and perhaps other, questions are adequately answered then it is important to consider several issues such as the rationale, objectives, level, time horizon, duration, cost, an so on. In Box 1 those issues are discussed in greater detail.

Box 1. Characteristics of the Foresight Exercise

1. Rationale. What are the arguments for conducting the foresight exercise? Although the rationale depends upon the sponsors and stakeholders involved, usually the justification emphasizes how things can be done better with the help of foresight.

2. Objectives. What will the foresight exercise achieve and by when? There may be objectives at different levels, depending on the actors involved, and they may also have different objectives for a foresight exercise as a whole.

3. Review existing arrangements for strategic decision-making. How will the foresight exercise complement or challenge those arrangements? Will it be a relatively isolated activity or be embedded in

existing strategic processes where it feeds into the strategies of the different actors?

4. Orientation. What will be the focus of the foresight exercise? Foresight can have any number of orientations (such as some societal problems, science and technology, business dynamics, territorial visions, and so on). The orientation is related the rationale and objectives of the exercise, and therefore depends on the agendas of the actors involved.

5. Level. At what political, economic, social, institutional, and/or geographical level is the foresight exercise to be carried out? A foresight exercise may focus on global/national/regional levels; may be practiced at the level of a government, firm, or NGO; may cover a specific productive sector, and so on.

6. Time horizon. What is the time horizon for the foresight exercise? The average time horizon for national foresight exercises may go from five years to 30-50, although many appear to be around 10-15 years. The time horizon adopted is usually related to the focus, objectives, and intended uses of the foresight exercise. It should be noted that even though the time horizon for the analysis extends into the future, foresight exercises need to consider both the past (in the form of historical trends that are defining the current situation), and the present (to the extent that the exercise may lead to changes in current strategies and policies).

7. Coverage. What sectors/issues/problems will the foresight exercise seek to cover? It is usually necessary to select the sectors/issues/problems to be covered by the foresight exercise, in part because of resource constraints and the need to organize exercises of manageable proportions.

8. Participation. What should be the breadth of actor engagement in the foresight exercise? Who participates in a foresight is a central issue to produce results that are perceived as legitimate and relevant, and that can be implemented. Who participates is obviously influenced by the scope, objectives, orientation, themes/sectors covered, and the intended audience of the exercise.

9. Consultation. What should be the depth of actor engagement in foresight exercise, both in terms of frequency and reach? This is different from the direct participation mentioned in 8, which happens through more involved work with experts and stakeholders in activities such as Delphi surveys or scenario workshops. Separate from that participation, there may be moments in a foresight exercise where views might be requested outside the participating group, for example, during the process of defining the scope and objectives of the exercise, and later during the discussion of the implications of the foresight's results. Appropriate consultation would allow participants to make strategic choices about an exercise, and to generate greater ownership of the process and outputs. The reach of the consultation may be widespread or narrow, which will have implications for the credibility of the foresight exercise, and the time and cost involved.

10. Duration and cost. How long does a foresight exercise last and how much does it cost? This will depend on the other elements discussed above, such as the areas covered and the number of people

participating directly or being consulted. Shorter exercises may be repeated at different points in time. There are also exercises that can be done on a continuous basis.

11. Methods. There is a variety of methods, as discussed elsewhere in this document, each one presenting different advantages and disadvantages depending on the issues considered.

12. Organization and management. There are different potential ways of organizing the work, depending on decisions on previous issues analyzed here. Usually, the organization includes steering committees and different types of panels of experts and stakeholders.

13. Dissemination. The results of the foresight exercise need to be disseminated, particularly to those that are expected to act on the findings and recommendations. Messages need to be tailored into messages that are understandable by the audience intended. Besides considering the content, also the vehicle through which messages will be transmitted needs to be carefully analyzed.

14. Implementation. In many cases, successful implementation requires follow-up actions by actors that may not have been directly involved in an exercise. If there are crucial actors for follow-up implementation, then it is important to make sure that they have been involved in the exercise at some point.

15. Evaluation. There must be a mechanism to evaluate whether the foresight exercise has met its objectives.

Source: European Foundation for the Improvement of Living and Working Conditions (2003).

3.4 OUTPUTS AND OUTCOMES FROM A FORESIGHT EXERCISE

Foresight exercises may produce formal or tangible results, incorporated into products and deliverables such as reports, workshops, formation of networks, establishment of web-sites, and so on. Usually the reports include recommendations to policy-makers or corporate executives, and/or may also cover elements such as scenario descriptions, survey results, critical technology lists, sectorial analyses, and so son. Of course, the most important results from foresight exercises go beyond the immediate outputs, and include facilitation of planning and policy development, adoption of policy recommendations, the institutionalization of participatory foresight in the planning process, and the facilitation of implementation of required actions. But there are also more informal or intangible ones that may derive from the foresight process itself or the dissemination of results, such as development of informal networks, generating consensus on common visions of future opportunities and challenges, influencing a societal debate by placing a topic in the policy conversation, fostering a culture of thinking ahead in a participatory manner, and so on (UNIDO, 2005; and European Foundation for the Improvement of Living and Working Conditions, 2003).

3.5 THE METHOD OF SCENARIOS

In what follows, qualitative and quantitative scenarios are discussed in greater detail, considering that a) scenarios are so widely used that sometimes have been taken as equivalent to the notion of foresight studies, and b) that the other methods are sometimes utilized for scenario building activities as well.

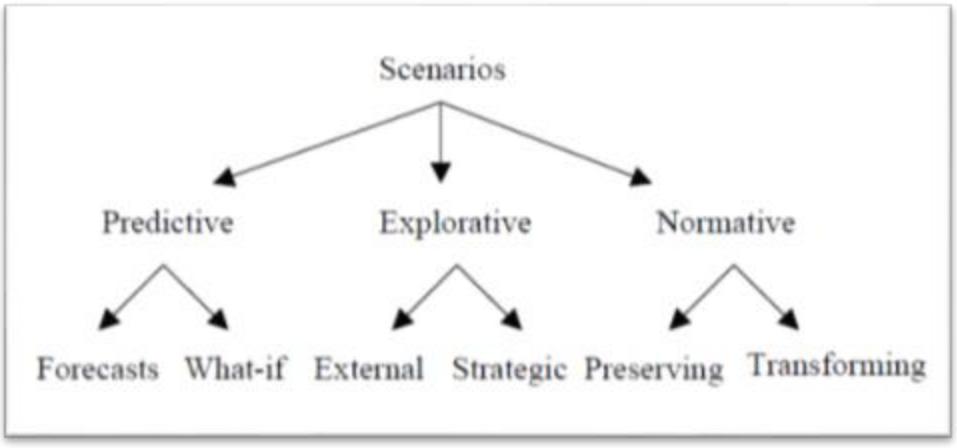
3.5.1 DEFINITION

Michael Porter (2004) has defined scenarios in the context of business strategies as "an internally consistent view of what the future might turn to be -not a forecast, but one possible future outcome." In global exercises, both the IPCC work (2001) (see also Nakicenovic et al, 2000) and the Millennium Assessment (2005) define scenarios as "plausible descriptions of how the future may develop, based on a coherent and internally consistent set of assumptions about key relationships and driving forces."

3.5.2 TYPES OF SCENARIOS

Borjeson et al (2005) present a typology with three basic types based on the main questions a user may ask about the future:[11] a) what will happen; b) what can happen; and c) how can a specific target be reached. Based on the question answered they identify three types of scenarios: Predictive (first question), Exploratory (second question), and Normative (third question). Further, they divide each scenario in two subcategories, depending on some additional criteria related to how the main question is answered (Figure 1).

Figure 1. Type of Scenarios



Source: Borjeson et al (2005)

[11] What follows is based on Borjeson et al 2005.

For instance, Predictive Scenarios are divided into Forecasts and What-if scenarios. Forecasts answer what will happen based on the most likely developments given the evolution of the external factors considered (although they may have a range of "high", "medium" and "low" alternatives, or if the quantitative technique utilized allows it, there may be probabilities attached to the trajectories). What-if scenarios, on the other hand, investigate futures under the assumption that some specified events of great importance take place along the temporal axis, usually, but not always, at the beginning of the projected time period or in the near future. These events may be new policy decisions and/or changes in key trends or variables that were assumed to be more constant (or invariant) under the basic forecast scenario. There may be several what-if scenarios, and none of them is considered to be the most likely one. Exploratory Scenarios, which answer the question about "what can happen," are also separated in Borjenson et al (2005) into two types: one is called "External Scenarios" and the other "Strategic Scenarios." External Scenarios consider what can happen given the development of certain external factors beyond the control of the relevant actors, while Strategic Scenarios focus on what can happen if the relevant actors take certain decisions of strategy and policy. Changes in strategies and policies are not part of the External Scenarios, but are the key in Strategic Scenarios. One objective of the foresight exercises is to develop robust strategies and policies that make sense under different kinds of external events.

It should be noted that the differences between Predictive/Forecasts and Exploratory/External Scenarios, as well as between Predictive/What-if and Exploratory/Strategic Scenarios may not be that clear cut. The distinction may depend on the time horizon and/or the level of uncertainty involved, with the Predictive Scenarios, usually more short-term oriented and/or working under stronger assumptions about the level of knowledge available to conduct those exercises.

The Normative Scenarios, which answer the third question about how can specific targets be achieved, are also divided by Borjenson et al (2005) in two other alternatives. The first one is Preserving Scenarios, which working within the existing structures, try to determine how a target can be reached by some adjustments to the current situation, usually looking for efficient (or optimal, under some definition of optimality) ways to do that. Transforming scenarios, on the other hand, look at the issue of achieving targets when prevailing trends and structures would impede such objective without major adjustments. In this second case, the analysis starts from highly desirable objectives and work backwards ("backcasting"), trying to identify the changes needed to reach the postulated visions.

Borjenson et al (2005) summarize the typology as follows: "If the user wants to predict the future, forecasts and what-if scenarios are of interest. If the user wants to think in terms of several possible futures, perhaps in order to be able to adapt to several different types of outcomes, explorative scenarios may be useful. If the user wants to search for scenarios fulfilling specific targets, and maybe link this to actions that can be taken towards the visions, normative scenarios should be the choice. Those three

approaches to scenario studies are different. The choice of scenario category is not only a question of the character of the studied system. Instead, the user's worldview, perceptions and aim with the study can be even more important for the choice of approach."[12]

3.5.3 USES OF SCENARIOS

There are a variety of uses for scenarios: to start a discussion and generate ideas, to test the consistency and robustness of assumptions, to identify main uncertainties and the need for more information, to exchange visions and strengthen linkages in networks, to try to communicate ideas and influence a debate, to evaluate a range of strategies and policy options considering the existence of alternative futures, and so on (UNIDO, 2005; and European Foundation for the Improvement of Living and Working Conditions, 2003). Scenarios offer planners and decision-makers different visions of what the future may hold, helping them to move from optimization against a specific future target, and towards a more balanced evaluation of the range of strategies and policies that may be required to cope with the alternative futures (UNIDO, 2005).

3.5.4 CONSTRUCTION OF SCENARIOS

As it is noted in UNIDO (2005), "the ways of producing scenarios vary immensely from the outputs of simulation models through the work of small expert teams, to the undertakings of workshops and the delineation of different views in even wider samples of expertise." Usually the construction of scenarios go through a sequence of steps: 1) identification of the focal issue or decision; 2) determination of the key drivers, forces and trends shaping the issue considered; 3) analysis of the importance of the driving forces and trends, their cross-influences and relations, and the levels of uncertainty involved; 4) definition of the scenario logic and main storylines; 5) development of the story lines for the number of scenarios selected; 6) assessment of the implications for strategy definition and for policy decision-making: what are the strategic options for the key actors considered in relation to the scenarios defined , both to achieve good outcomes, or to cope with bad ones; and 7) selection of adequate indicators and benchmarks for monitoring and evaluation (UNIDO, 2005).[13]

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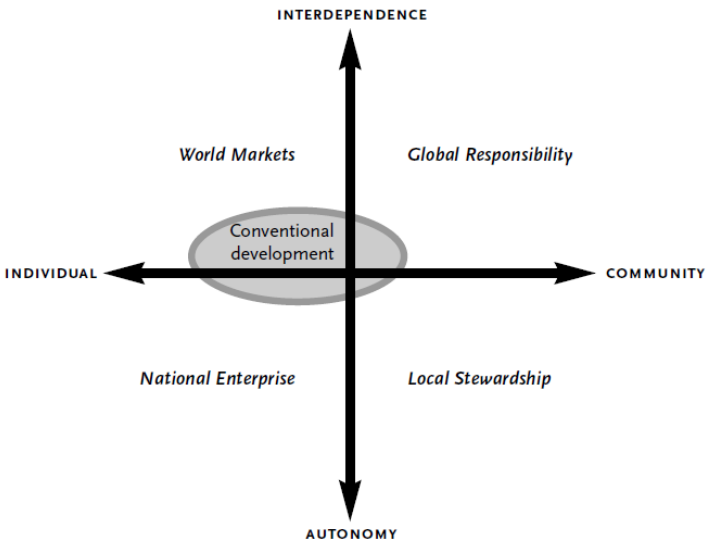
[12] Michael Reilly and Dirk Willenbockel (2010), for instance, utilize this typology to categorize five main efforts of scenario analysis and modeling for global food systems: FAO's World Agriculture Towards 2030/2050, by Alexandratos et al (2006); the Comprehensive Assessment of Water Management in Agriculture (CAWMA), by Fraiture et al. (2007), global food production scenarios based on climate change studies by the Intergovernmental Panel on Climate Change (IPCC) (Parry et al., 2004), the Millennium Ecosystem Assessment (MA) scenarios, and the Agrimonde 1 scenario.

[13] A very elaborate process of construction of scenarios was followed by the Millennium Assessment (2005), which combined quantitative and qualitative efforts as well as widespread consultation and multi-scale analyses (see also Carpenter et al, 2005).

After defining the focus of the analysis, other important component is the definition of strategic dimensions and drivers. For instance, the MA defines the following variables as indirect drivers (because the study focuses on climate impacts on services from the ecosystem, there are other more direct drivers at this level): a) population development, including total population and age distribution; b) economic development, defined by expected growth in per capita GDP and changes in economic structure; c) technology development, including assumptions on the evolution of many key variables such as the rate of improvement in water-use efficiency and the rate of increase in crop yields; d) human behavior, with different assumptions about things like the willingness of people to follow more or less conservationist approaches to water or energy; e) institutional factors, affecting issues such trade or technology transfers (Alcamo et al, 2005). Figure 2 (from Berhout and Hertin, 2002) shows another way of organizing basic drivers. They consider only two main dimensions, called "values" (i.e contemporary tastes, beliefs and norms), and "governance" (indicating the way in which authority and power is exercised in societies at the local, national or global levels, including not only governments but non-governmental actors as well). They consider both dimensions "to be foundational determinants of future change," reflecting contemporary political and social debates in the United Kingdom "about the nature of government, the role of the market, political relationships within the European Union and the social control of new technologies" (Berkhout and Hertin 2002). Those two dimensions define four scenarios as shown in Figure 2 (where the four scenarios are also named).

Figure 2. Drivers organizing by Berkhout and Hertin, 2002.



Note: the horizontal axis represents values; the vertical axis represents governance.

Source: Berkhout and Hertin, 2002.

The following Table 2 (also from Berkhout and Hertin, 2002) shows the framework in greater detail

Table 2. An Example of Possible Drivers and Scenarios

	World Markets	*National Enterprise*	*Global Responsibility*	*Local Stewardship*
DRIVERS				
Social values	▸ Internationalist ▸ Libertarian	▸ Nationalist ▸ Individualist	▸ Internationalist ▸ Communitarian	▸ Localist ▸ Co-operative
Governance structures	▸ Weak ▸ Dispersed ▸ Consultative	▸ Weak ▸ National ▸ Closed	▸ Strong ▸ Co-ordinated ▸ Consultative	▸ Strong ▸ Local ▸ Participative
Role of policy	▸ Minimal ▸ Enabling markets	▸ State-centred ▸ Market regulation to protect key sectors	▸ Corporatist ▸ Political, social and environmental goals	▸ Interventionist ▸ Social and environmental goals
ECONOMIC TRENDS				
Economic development	▸ High growth ▸ High innovation ▸ Capital productivity	▸ Medium to low growth ▸ Low innovation ▸ Maintenance economy	▸ Medium to high growth ▸ High innovation ▸ Resource productivity	▸ Low growth ▸ Low innovation ▸ Modular and sustainable solutions
Structural change	▸ Rapid ▸ Towards services	▸ More stable economic structure	▸ Fast ▸ Towards services	▸ Moderate ▸ Towards regional systems
Fast-growing sectors	▸ Health and leisure ▸ Media and information ▸ Financial services ▸ Biotechnology ▸ Nanotechnology	▸ Private health and education ▸ Domestic and personal services ▸ Tourism ▸ Retailing ▸ Defence	▸ Education and training ▸ Large systems engineering ▸ New and renewable energy ▸ Information services	▸ Small-scale manufacturing ▸ Food and organic farming ▸ Local services
Declining sectors	▸ Manufacturing ▸ Agriculture	▸ Public services ▸ Civil engineering	▸ Fossil fuel energy ▸ Traditional manufacturing	▸ Retailing ▸ Tourism ▸ Financial services
SOCIAL TRENDS				
Unemployment	▸ Medium to low	▸ Medium to high	▸ Low	▸ Medium to low (with a larger voluntary sector)
Income	▸ High	▸ Medium to low	▸ Medium to high	▸ Low
Equity	▸ Strong decline	▸ Decline	▸ Improvement	▸ Strong improvement
Areas of conflict	▸ Social exclusion ▸ Immigration and emigration ▸ Political accountability	▸ Unemployment ▸ Poor public services ▸ Inequality	▸ Structural change ▸ Change of skills ▸ Political accountability and institutional rigidity	▸ Land-use conflicts ▸ Under-investment ▸ Environmental restrictions

Source: Berkhout and Hertin, 2002.

Another question to be answered is how many scenarios to construct. Using only two scenarios is considered too restrictive, while utilizing three has been criticized considering that people may take the middle one as the "desired scenario." Many exercises appear to settle on four scenarios. In some cases the four scenarios are the result of selecting two main dimensions (as in Berkhout and Hertin, 2002). In other cases, the number results from constructing 1) a "best guess" extrapolation of current developments; 2) a "hard-times" scenario; 3) an "aspirational" or "visionary" scenario; and 4) a "structurally different" scenario, that may define a paradigm shift, which does not have to be "bad" (as in 2) or "good" (as in 3) (European Foundation for the Improvement of Living and Working Conditions, 2003). Van Vuuren et al (2012) analyzing a variety of foresight studies identified six families of scenarios that seem to be repeated in most exercises (this study is discussed later).

In any case, it is important to keep in mind the cautionary comments by Reilly and Willenbockel (2010) about the technical, methodological, and epistemological problems posed by the construction of scenarios and by foresight methods in general: "There are technical uncertainties concerning the quality of data available to calibrate the model and to determine input assumptions for drivers of change. There are methodological uncertainties because we may lack sufficient knowledge to create an adequate model form with suitable structure and functional forms of behavioural equations. Epistemological uncertainties refer to the completeness of the model: changes in human behaviour and values, randomness of nature, technological surprises and so-called high impact, high uncertainty 'black swan' events may all be unknowable (…) Furthermore, a complex system may be fundamentally indeterminate."

3.6 FINAL COMMENTS ON METHODS

The discussion of foresight so far, shows that there is a wide variety of approaches, with different and legitimate applications. In terms of the work of CIAT and the CGIAR centers, different methods can be utilized depending on the level and focus of analysis. For instance, simulation models and quantitative scenarios (such as those produced with IFPRI's IMPACT model and variations, or different CGE models) and global qualitative scenarios, can be used at a world, regional, or national scale, while more focused methods (such as Delphi, Critical Technologies and Technology Road-mapping) can be utilized for specific problems, areas, agricultural activities, and/or types of producers.

Certainly, it does not exist a single method that can address all the questions and issues posed by foresight analysis. As it was mentioned before, the GCARD Road Map mentioned that foresight exercises should be done through multiple "lenses," considering that each approach "may resolve only part of the story, but together they can produce collective best-bets on future needs." It would be a mistake to concentrate on defining and enforcing only one methodology, such as qualitative scenario planning or any

other. Each one has its area of application. It is also necessary not to embark development countries in very costly exercises, when simpler methods of planning and priority setting would suffice for the decision at hand. In this document, the foresight method utilized will be the scenario approach, but there will be references to other methodologies.

4 LAC'S AGRICULTURE AND FOOD DEVELOPMENTS: LOOKING TO THE PAST, THINKING ABOUT THE FUTURE

Prospective analysis usually benefits from a consideration of the past for at least two reasons: first, the current situation is the starting baseline for the future scenarios; and second, the trends and drivers that shaped the current situation may well be operative in the future as well. Therefore, we begin this foresight scenario for LAC briefly considering some general issues in LAC's agriculture and food developments.[14] Recognizing that there is an important heterogeneity in LAC agriculture, in this document we present some indicators for the region as a whole, but at the same time we try to make some distinctions in different variables.[15] In what follows we discuss some indicators of the evolution of LAC agriculture since the 1960s (data from FAOSTAT accessed during April-July 2012).

4.1 FOOD AVAILABILITY

First, food availability per capita measured in calories, proteins and fat, has increased between the 1960s and the 2000s (Table 3). LAC sub-regions have maintained larger absolute values of food availability than the world average, except for the case of the Caribbean region, where Haiti has a large incidence.

[14] Reviews of the evolution of LAC's agriculture covering several decades include Pardey, Wood, Wood-Sichra, Chan-Kang, and You (2009), Salles et al (2009), Sain and Ardila (2009), and World Bank (2005).

[15] If a global view is taken, LAC countries share some commonalities, depending on the variables utilized. For instance the 2008 World Bank Development Report on Agriculture divides developing countries according to a) the share of aggregate growth originating in agriculture and b) the share of aggregate poverty in the rural sector (measured with the US$ 2.15/day poverty line, at purchasing power parity, PPP). Using those indicators, the report clusters developing countries in three categories: "urbanized countries," where agriculture's contribution to growth is lower and poverty is not rural; "transforming countries," where agriculture, while having a somewhat larger contribution to growth, it is still not the main growth factor, but poverty is mostly rural; and "agriculture-based countries," where agriculture contributes significantly to growth and poverty is rural. This classification considers 14 LAC countries: Argentina, Bolivia, Brazil, Colombia, Chile, Dominican Republic, Ecuador, Guatemala, Honduras, Mexico, Peru, Paraguay, El Salvador, and Venezuela. Eleven of those countries, with 88% of the population of the LAC countries considered, are classified in the "urbanized" category. Two countries (Guatemala and Honduras) are considered within the "transforming" category (which at the world level mostly includes Asian developing countries); and one country (Paraguay) is in the "agriculture-based" category (in the global analysis this group mostly includes countries from Sub Saharan Africa). Regarding food security a cluster analysis (using data from the 1990s) places eight LAC countries in food insecure categories, but most of the LAC countries are in neutral categories (see Diaz-Bonilla, Thomas, Robinson, Cattaneo, 2006).

Table 3. Food Availability in LAC region

Food Availability		Average 1960s	Average 2000s	% increase
Caribbean	Calories (kcal/capita/day)	2121	2584	21.8
Mexico and Central America	Calories (kcal/capita/day)	2292	2999	30.9
South America	Calories (kcal/capita/day)	2378	2857	20.1
World	Calories (kcal/capita/day)	2288	2782	21.6
Caribbean	Proteins (g/capita/day)	51	61	21.2
Mexico and Central America	Proteins (g/capita/day)	62	84	36.1
South America	Proteins (g/capita/day)	64	79	23.5
World	Proteins (g/capita/day)	63	77	22.1
Caribbean	Fat (g/capita/day)	47	62	33.7
Mexico and Central America	Fat (g/capita/day)	49	84	70.4
South America	Fat (g/capita/day)	52	91	73.3
World	Fat (g/capita/day)	51	78	52.5

Source: Calculated by Authors, from FAOSTAT

4.2 PRODUCTION

The previous indicators cover all food availability, including imports. The following Tables show the growth rates of agricultural and food production, in total and per capita terms, during the last half a century. Data reflects the value of production in constant international dollars (as different from constant common dollars[16]). Therefore the variables can be considered a "quantity" indicator of the agricultural and food production.[17]

[16] International dollars are used to avoid fluctuations in the total value of aggregates due to changes in market exchange rates. It is a form of adjustment for purchasing power parity, using the Geary-Khamis approach, by which each commodity has a single world price per relevant unit of volume, irrespective of the country where it was produced. This approach facilitates aggregations and comparisons across countries.

[17] As any aggregate indicator, such as the GDP, the food or agricultural quantity indicator captures not only a greater "volume" of the items that are aggregated through a common set of prices, but also whether the composition of the whole is changing towards individual components with higher unitary prices. In other words, as the GDP may grow not only because the country is producing more of everything but because it is producing more cars instead of, say, informal services, in the same way the "quantity" of agricultural and food products may increase because there is more production of higher-value items.

Table 4. Growth Total (% year)

GROWTH TOTAL (% year)						
AGRICULTURE						
	1960s	1970s	1980s	1990s	2000s	1961/2010
World	2.6	2.5	2.3	2.3	2.3	2.4
European Union	2.0	2.3	0.7	0.6	-0.3	1.0
USA+Canada	2.1	2.7	1.0	2.4	1.3	1.9
Australia+New Zealand	3.5	2.3	0.9	3.1	0.1	2.0
Asia	3.2	3.0	4.0	4.3	3.0	3.5
China	4.7	3.7	5.1	5.9	3.3	4.5
India	1.7	2.4	4.2	2.9	2.6	2.8
Asia w/o China, India, Japan	3.0	3.1	3.5	3.9	3.1	3.3
Africa	3.2	1.5	2.9	3.4	3.0	2.8
LAC	3.1	3.1	2.5	3.2	3.1	3.0
FOOD						
	1960s	1970s	1980s	1990s	2000s	1961/2010
World	2.7	2.6	2.4	2.4	2.3	2.5
European Union	2.0	2.3	0.7	0.6	-0.3	1.1
USA+Canada	2.4	2.7	1.1	2.4	1.4	2.0
Australia+New Zealand	3.6	2.7	0.7	3.6	0.5	2.2
Asia	3.1	3.1	4.0	4.4	3.0	3.5
China	4.4	3.8	4.9	6.2	3.3	4.5
India	1.7	2.4	4.3	2.9	2.4	2.7
Asia w/o China, India, Japan	2.9	3.2	3.6	3.9	3.2	3.4
Africa	3.1	1.7	3.0	3.5	3.1	2.9
LAC	3.5	3.3	2.7	3.4	3.1	3.2

Source: Calculated by Authors, from FAOSTAT, 2012.

Clearly, agricultural and food production in LAC has grown faster than in developed countries and Africa, but slower than Asia as a whole (although LAC's performance has been better than India's). The best decades for LAC have been the 1960s and 1990s, and the worst decade was the 1980s during the "lost decade" of the debt crisis, when slow domestic growth and decline in world prices combined to reduce agricultural development. The 2000s was also a decade of strong growth, similar to the 1990s, until the negative impact in 2008/2009 of, both, climate events and the global financial crisis. While the previous Table 4 showed total growth, the next one considers growth in per capita terms.

Table 5. Agriculture and Food Growth Rate in per capita terms (% year)

GROWTH PER CAPITA (% year)						
AGRICULTURE						
	1960s	1970s	1980s	1990s	2000s	1961/2010
World	0.6	0.6	0.6	0.8	1.0	0.7
European Union	1.1	1.8	0.4	-0.2	-0.7	0.4
USA+Canada	0.8	1.7	0.0	1.3	0.4	0.8
Australia+New Zealand	1.4	0.7	-0.4	1.9	-1.3	0.4
Asia	0.9	0.8	2.0	2.5	1.8	1.6
China	2.5	1.6	3.5	4.8	2.7	3.0
India	-0.4	0.0	1.9	0.9	1.0	0.7
Asia w/o China, India, Japan	0.4	0.7	1.0	1.2	1.6	1.0
Africa	0.7	-1.2	0.1	0.8	0.6	0.2
LAC	0.4	0.7	0.4	1.5	1.8	1.0
FOOD						
	1960s	1970s	1980s	1990s	2000s	1961/2010
World	0.7	0.6	0.6	0.9	1.1	0.8
European Union	1.2	1.8	0.4	-0.2	-0.6	0.4
USA+Canada	1.1	1.7	0.1	1.3	0.4	0.9
Australia+New Zealand	1.5	1.2	-0.7	2.3	-0.9	0.6
Asia	0.8	0.9	2.0	2.6	1.8	1.6
China	2.2	1.7	3.3	5.1	2.7	3.0
India	-0.4	0.0	1.9	1.0	0.9	0.7
Asia w/o China, India, and Japan	0.3	0.8	1.1	1.2	1.7	1.0
Africa	0.5	-1.0	0.2	0.9	0.8	0.3
LAC	0.8	0.8	0.6	1.7	1.8	1.2

Source: Calculated by Authors, from FAOSTAT

Given the relatively strong total growth and comparatively smaller increases in population with respect to other developing regions, when growth is measured in per capita terms, LAC is performing better not only than the developed countries, Africa and India (as before), but also above the rest of Asia (i.e. excluding China, India and Japan; these three countries represent about 2/3 of the value of agricultural and food production in Asia, although their relative importance has been changing with Japan losing, and China gaining, share).

Another way of looking at the evolution of LAC at the global level is to consider the share of the region in world agricultural and food production. The next Tables present the evolution of shares of agricultural and food production for selected regions and countries that in the decade of the 2000s represented about 96% of world agricultural and food production.

Table 6. Share of the World Agricultural Production (%).

Share of World Agricultural Production (%)					
	1960s	1970s	1980s	1990s	2000s
European Union	21.6	20.5	18.8	15.7	12.4
USA+Canada	15.2	14.8	13.6	12.8	11.8
Australia+New Zealand	2.2	2.2	2.0	1.9	1.7
Subtotal	39.1	37.5	34.4	30.4	26.0
Asia	31.0	32.4	36.8	44.7	49.3
China	9.8	10.7	13.4	18.4	22.2
India	8.1	8.2	8.8	9.8	9.8
Asia w/o China, India, Japan	10.9	11.5	12.9	15.1	16.3
Africa	7.5	7.4	7.0	7.8	8.4
LAC	9.9	10.4	11.0	11.3	12.6
Argentina	2.1	2.0	1.9	1.8	1.9
Brazil	3.0	3.4	4.2	4.6	5.6
Mexico	1.4	1.5	1.7	1.6	1.6
Rest	3.4	3.5	3.3	3.4	3.4
Total	87.5	87.7	89.3	94.2	96.3

Source: Calculated by Authors, from FAOSTAT

Asia, pushed mainly by China's growth and to a smaller degree by the rest of Asia (not including India and Japan), has gained the largest global share (18 percent points), while the traditional agricultural producers and exporters among industrialized countries lost about 13 percent points in world's total production. LAC increased its share in almost 3 percent points, but this has been due mainly to Brazil's performance, considering that Argentina lost some share, while Mexico did not gain much, and the Rest of LAC stayed about the same. Other point worth noting is that in the 2000s LAC's agricultural production has grown somewhat bigger in size than, both, the European Union, on the one hand, and the United States and Canada, on the other. Also it is important to note that, although it is true that Argentina, Brazil and Mexico represent about 63% of LAC's agricultural production, the rest of the region has a total share comparable to Argentina and Mexico combined. An implication is that LAC's agriculture cannot be analyzed looking only at the three main countries. Next Table 7 looks at world shares of food production.

Table 7. Share of the World Food Production (%)

Share of World Food Production (%)					
	1960s	1970s	1980s	1990s	2000s
European Union	22.7	21.5	19.6	16.3	12.9
USA+Canada	15.3	14.9	13.8	12.9	11.9
Australia+New Zealand	2.1	2.1	1.8	1.8	1.7
Subtotal	40.0	38.4	35.3	31.0	26.4
Asia	30.6	32.0	36.2	44.1	48.7
China	9.8	10.6	13.1	18.3	22.2
India	8.1	8.2	8.8	9.8	9.7
Asia w/o China, India, Japan	10.6	11.1	12.5	14.6	15.8
Africa	7.3	7.2	6.9	7.7	8.4
LAC	9.4	10.1	10.8	11.3	12.6
Argentina	2.1	2.0	1.9	1.8	1.9
Brazil	2.7	3.3	4.0	4.5	5.6
Mexico	1.3	1.5	1.7	1.6	1.7
Rest	3.2	3.3	3.2	3.3	3.4
Total	87.3	87.7	89.2	94.1	96.1

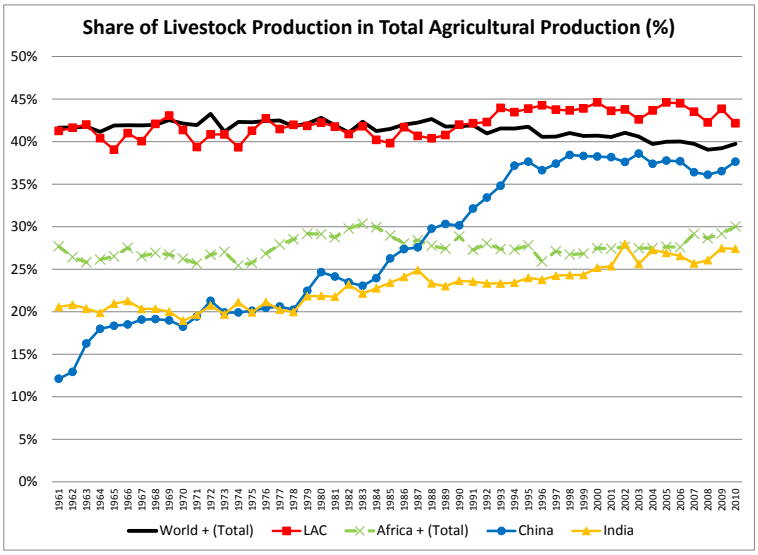
Source: Calculated by Authors, from FAOSTAT

The trends are not much different from those noted in the Table of world shares in agriculture. The world share of food producers from industrialized countries also declined, but somewhat less than for total agriculture, and Asia increased its share, but also not as much as for all agriculture. The main difference is in the rest of Asia that has a larger share of agriculture than of food production. In the case of LAC, the numbers are similar for agriculture and food production, so the previous comments apply here as well, in particular the importance of Brazil's growth for the increase in LAC's share of world food production (somewhat more than 90% of LAC's increase in share comes from Brazil).

FAO's data divides agricultural production into two parts, each one with two components: crops and livestock, on the one hand; and food and non-food, on the other (it has also aggregate data on cereals as a separate component). Since it was labeled as the "livestock revolution" (see Delgado et al, 1999), the trend towards the increase in the production of meat, dairy and related products in developing countries has continued. Figure 3 shows changes in the share of livestock in agricultural production for the world and different developing regions and countries. Several aspects may be highlighted (it should be kept in mind that these are shares with respect to the same region or country, not the world; this second indicator will be discussed immediately below). First, the share of livestock as part of total agricultural production at the world level has remained relatively flat at around 40% (although there has been a small decrease of the share in the last decades). Second, this stability results from opposing movements: a decline in

livestock production shares mainly in some industrialized and Eastern European countries (not shown in Figure 3), and important increases in the livestock share in developing regions and countries, particularly China, and to a lesser degree in India. Third, in a general context of increasing shares in total agricultural production, livestock is a far more important component of total agricultural production in LAC (where it moved from close to 40% to about 45% of total agricultural production) than for the world as a whole and for other developing regions and countries; this fact should be considered when discussing R&D priorities. Fourth, India has a lowest share than Africa, although it has grown from about 20% to more than 25%. Fifth, the structural change toward livestock production in China has been very large, with the livestock share moving from close to 10% in the 1960s to about 37-38% in the 2000s; the share, however, seems to have stabilized around those values since the 1990s.

Figure 3. Share of Livestock Production in Total Agricultural Production (%)



Source: Calculated by Authors, from FAOSTAT

It is not a surprise then that the increase of the share of developing countries in world total agriculture (discussed before in relation to Tables 6 and 7) reflects mostly the change in composition towards more livestock production. The next Table 8 looks at the components of crops and livestock and shows the impact of each one in the changes of world shares of agricultural products.

Table 8. Livestock World Share (%)

WORLD SHARES (%)						
LIVESTOCK	1960s	1970s	1980s	1990s	2000s	Difference 2000s/1960s
European Union	27.1	27.1	25.4	21.3	17.3	-9.8
USA+Canada	21.4	19.0	16.8	16.0	15.1	-6.3
Australia+New Zealand	4.2	4.0	3.4	3.3	3.0	-1.2
Subtotal	52.7	50.2	45.6	40.6	35.5	-17.2
Asia	15.6	17.3	22.5	33.4	39.8	24.2
China	4.0	5.2	8.4	16.1	20.8	16.8
India	4.0	3.9	4.8	5.6	6.5	2.5
Asia w/o China, India, Japan	6.3	6.4	7.3	10.0	11.2	4.9
Africa	4.8	4.7	4.8	5.1	5.9	1.1
LAC	9.8	10.1	10.8	11.9	13.7	3.9
Argentina	3.1	2.6	2.2	2.0	1.8	-1.3
Brazil	2.5	3.0	3.7	4.8	6.2	3.7
Mexico	1.2	1.5	1.8	1.8	2.0	0.8
Rest LAC	2.9	3.0	3.0	3.3	3.6	0.7
Total	82.9	82.3	83.7	91.0	94.9	
CROPS						
European Union	19.4	17.3	15.4	12.8	10.3	-9.1
USA+Canada	12.9	13.1	12.5	11.9	10.6	-2.2
Australia+New Zealand	0.7	0.8	0.9	1.0	0.9	0.2
Subtotal	33.0	31.2	28.7	25.7	21.8	-11.2
Asia	38.3	39.7	43.9	50.0	53.5	15.2
China	13.4	14.5	16.9	20.1	23.1	9.7
India	9.7	9.7	10.1	11.3	10.9	1.1
Asia w/o China, India, Japan	12.9	13.7	15.5	17.6	18.8	6.0
Africa	8.4	8.3	7.7	8.9	9.5	1.1
LAC	9.5	9.9	10.5	10.5	11.5	2.0
Argentina	1.3	1.4	1.5	1.5	1.8	0.4
Brazil	3.5	3.7	4.4	4.4	5.1	1.7
Mexico	1.3	1.4	1.5	1.5	1.4	0.1
Rest LAC	3.4	3.4	3.2	3.2	3.1	-0.2
Total	89.2	89.1	90.9	95.1	96.3	

Source: Calculated by Authors, from FAOSTAT

Although developing regions and countries have increased their share of world crop production (particularly China and the Rest of Asia), the largest differences appear in livestock production. For instance, Asia has increased its share of livestock products by about 24 percent points (pps) against 15 pps in crops. The numbers for China are 16.8 pps of increase in livestock share against 9.7 pps increase in crop share. In the case of LAC and Africa, again the increase in the livestock share is larger than the increase in crop share. Only in the cases of the Rest of Asia and Argentina (a country that lost world share in livestock production), crops account for a larger increase in share.

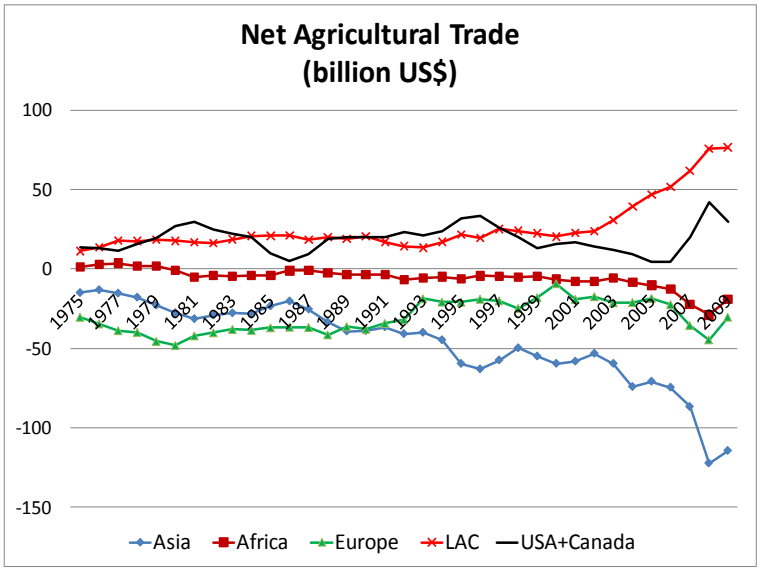
In summary, the increase in LAC's production and world share has been mostly related to the expansion of production in Brazil (considering countries) and livestock production (as opposed to crops). [18] As mentioned before, the comparatively larger share of livestock in LAC's total agricultural production is an important difference from other developing regions that must be considered when discussing R&D priorities in the region.

4.3 TRADE

The strong production performance has transformed LAC into the main net exporter of agricultural and food products, as can be seen in Figure 4, with the region surpassing USA and Canada combined. In fact, LAC as an agricultural net exporter surpasses USA, Canada, Australia and New Zealand together (the latter two countries are not shown in the next Figure).

Figure 4. Net Agricultural Trade (billion u$s)

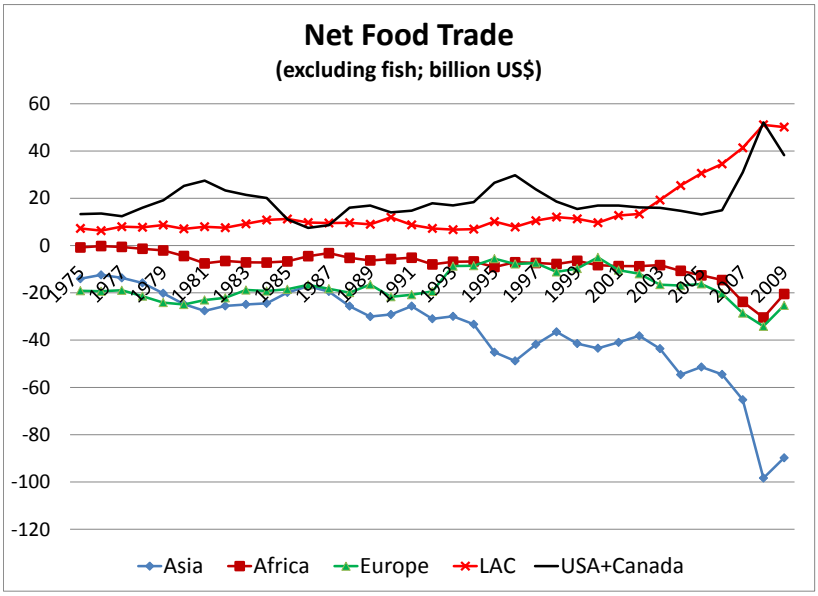
[18] As recently noted by CEPAL, FAO, IICA (2012) LAC's livestock has increased significantly in the last decade, and now represents about 14% of global stocks of the main species (beef, pork, lamb, poultry and milk cows), with the fastest expansión taking place in poultry stocks that grew almost 36% during the last decade. Brazil represents about half of all pork, livestock and milk cows, and some 40% of all poultry in the region. Besides increases in stocks, productivity also expanded significantly in the last ten years, with yields improving by 22% in milk, 15% in poultry, 14% in pork, and 7% in beef. All of this has led to significant increases in livestock exports for LAC as a whole since 2000: beef exports more than doubled, pork exports almost tripled, and poultry exports increased by close to five times.



Source: Calculated by Authors, from FAOSTAT

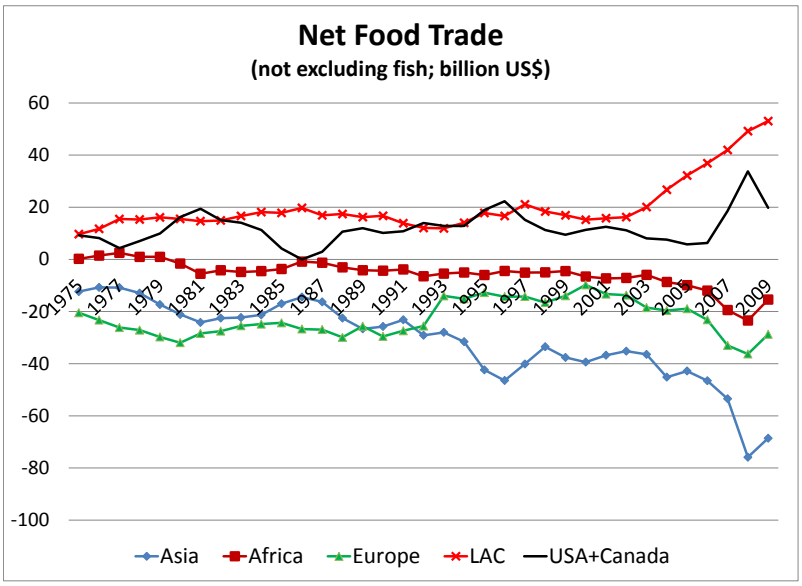
Figure 4 also implies that the Americas, as a whole, are the key surplus continent, and along with Australia and New Zealand (not shown) these countries represent the main agricultural net surplus regions. Figure 5 shows only net food exports (excluding fish). LAC continues to be the main global net exporter, but by a smaller margin. While the region still shows net food trade surpluses larger than USA and Canada combined, if Australia and New Zealand are also considered (not shown in the Charter), the combination of those industrialized countries makes them together a larger net food exporter than LAC. However, if fish is also included (Figure 6), the margin for LAC as a net food exporter increases and now it is larger than USA, Canada, Australia and New Zealand together

Figure 5. Net Food Trade (excludinh fish, in billion u$s).



Source: Calculated by Authors, from FAOSTAT

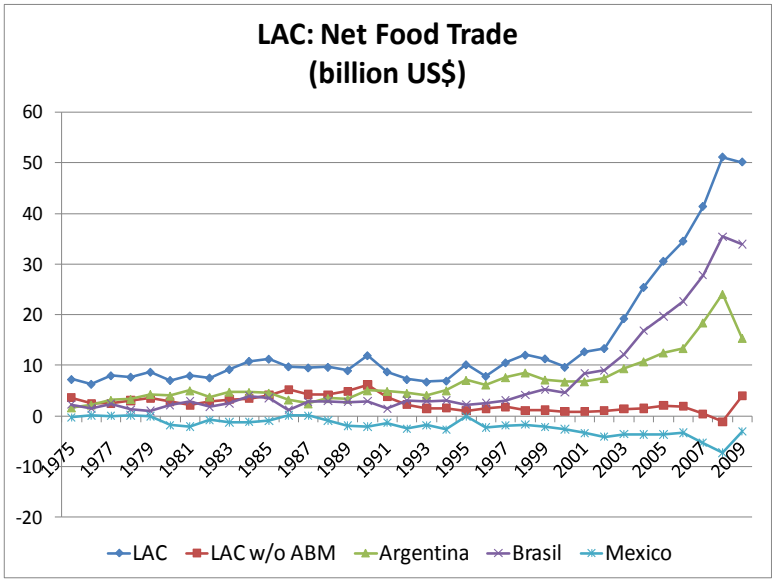
Figure 6. Net Food Trade (not excludinh fish, in billion u$s).



Source: Calculated by Authors, from FAOSTAT

The net trade surplus (see Figure 7, showing the food definition that excludes fish) has been generated mainly by Brazil and Argentina, with some contribution from the rest of LAC, while Mexico is a net food importer.[19]

Figure 7. LAC: Net Food Trade (billion u$s)

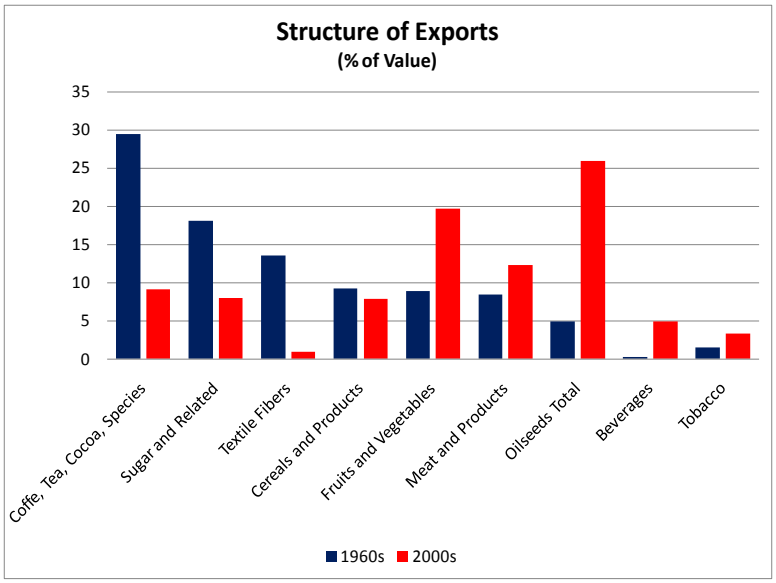


Source: Calculated by Authors, from FAOSTAT

The structure of agricultural trade for LAC changed significantly during the last decades. Figure 8 shows the percentage of different products in LAC's exports of agricultural products. This Figure presents how important a product may be for LAC's agricultural trade. Since the 1960s traditional tropical products, such as coffee, cocoa, sugar, and textiles have been losing share in LAC's agricultural exports, while fruits and vegetables, meat products, and oilseeds have increased their participation. Other products such as alcoholic beverages and tobacco have also expanded their share in agricultural exports. Table 9 shows LAC's exports for a specific product, as percentage of world exports of the same product. This share would indicate the importance for the world of LAC's exports of that product.

[19] It should be noted that even though these countries are net exporters, still many products have usually a larger orientation towards internal consumption, although the balance between exports and domestic consumption varies by countries and products. For instance in the case of Brazil during 2009, about 60% of soybean production, 90% of ethanol, some 70% for cotton and poultry, and over 80% of beef were destined to the domestic market (Contini, Pena, Santana, and Martha, 2012). Also in Argentina most of the wheat and beef production is for internal consumption.

Figure 8. Structure of Exports (% of value).



Source Calculated by Authors, from FAOSTAT

Table 9. LAC Exports as percentage of World Exports of the Same Product

	1960s	1970s	1980s	1990s	2000s
Total Merchandise Trade	6.7	5.1	5.0	3.9	4.7
Agricultural Products, Total	14.4	14.1	12.9	10.6	12.9
Food and Animals -0	17.7	17.1	15.5	11.8	13.3
Food Excluding Fish	12.1	12.6	11.8	10.0	12.9
Oilseed Cake Meal	17.2	26.7	39.9	45.9	53.7
Oilseeds -22	2.4	9.9	13.0	19.9	33.0
Sugar and Honey, Total	46.8	48.7	47.0	25.6	28.2
Coffee+Tea+Cocoa+Species-07	41.9	39.1	35.9	25.5	18.0
Fruit + Vegetables -05	10.8	10.8	13.4	15.0	15.5
Meat and Meat Prep -01	15.0	12.1	8.5	6.8	13.9
Meat Poultry Fresh	0.1	1.7	12.3	9.8	24.1
Animal and Vegetable Oil -4	9.9	9.2	12.2	13.0	14.0
Beverages + Tobacco -1	3.5	4.4	4.9	5.9	8.7
Cereals and Prep -04	7.4	6.3	5.3	5.6	7.7
Textile Fibers	15.7	12.9	8.5	6.0	5.4
Dairy Products and Eggs	0.8	0.8	0.7	1.5	3.0

Source: Calculated by Authors, from FAOSTAT

There are products in which the share in LAC's exports and in world's exports has increased, particularly oilseeds and related meal and oil products; and to a smaller degree, the same has happened to fruits and vegetables. Both groups of products are important for LAC and for the global market. Others, such as sugar and coffee, cocoa, tea, and species, have declining shares both in LAC's and world's exports. However, the global participation of LAC in these traditional products is still important (28% and 18%). Meat and meat products have a smaller percentage of global exports of that group compared to the 1960s, but the share has recovered from the declines in the 1980s and the low share of the 1990s; and, as it has been shown in Table 8, meat and products has expanded its share in LAC's total agricultural exports. To a large extent the decline is related to the closing of beef market in the European Union in the mid-1970s and its impact on Argentina, which has been compensated in part during the last decade by a jump in exports from Brazil and other LAC countries with a more diversified meat export structure (noticed the increase in the global share of poultry exports; to a lesser degree, pork exports (not shown here) have also increased its share).

Other products in which LAC has gained share are beverages and tobacco, and dairy products and eggs, but the participation of the region in total world exports of those products is smaller than 10% of the global market. In the case of cereals and products, LAC's global share has been relatively stable, at between 6-8%, which, considering also the relatively small share of those products in LAC's agricultural exports (see Figure 8), underscores the small role of those products for LAC's trade as whole (although this group of products is important for individual countries, such as Argentina, and, to a smaller degree and in a more recent development, for Brazil as well).[20]

4.4 LAND, LABOR, AND OTHER INPUTS

According to FAOSTAT database agricultural land (including crops and pastures) [21] at the global level increased in about 400 million hectares between the decades of the 1960s and 2000s. Table 10 shows how much of that change occurred in different producing regions. LAC is presented as a whole and

[20] Brazil has been a traditional net importer of cereals but since about mid-2000s the country has shown some net exports of cereals (in volume), pushed by net corn exports that have averaged about 7 million tons between since the mid 2000s and until 2010 (last year with full data in FAOSTAT). Still the country is a net importer of cereals and products, the broader category utilized in Table 9, which is reported in value not in volume,

[21] FAOSTAT uses "Agricultural Area" as the general category, which has different components such as "Arable Land," "Permanent Crops" and "Permanent Meadows and Pastures," which can be subdivided further. FAOSTAT estimated a total of about 4915.6 million hectares of total "Agricultural Area" (average for the 2000s), which includes about 1524.3 million hectares "Arable Land and Permanent Crops" and some 3391.3 million hectares of "Permanent Meadows and Pastures." This second category appears to be a general estimate to provide a comprehensive view of land use. In what follows we utilize the general category of "Agricultural Area" because it seems the most comprehensive estimation of land use, and it is particularly relevant for LAC given the large share of livestock production in the region.

disaggregated into Argentina, Brazil, Mexico and the Rest of LAC. The Table includes the same calculation related to increases in the global share for the value of agricultural production in constant dollars.

Table 10. Increases in Production and Area

Increases in Production and in Area								
	Net Production Value (constant 2004-2006; Million Int. $)				Agricultural Area (Million Ha)			
	1960s	2000s	Difference	% of World Change	1960s	2000s	Difference	% of World Change
Asia	228758.9	931765.9	703007.0	61.3	1082.3	1650.9	568.6	137.7
China	72788.6	420601.1	347812.5	30.3	356.0	528.8	172.8	41.8
India	60003.1	184603.3	124600.3	10.9	177.0	180.3	3.2	0.8
Asia w/o China, India, Japan	80801.0	308214.1	227413.1	19.8	542.3	937.1	394.8	95.6
LAC	72936.0	237100.2	164164.2	14.3	581.3	715.8	134.5	32.6
Argentina	15690.5	35891.2	20200.7	1.8	132.6	134.6	2.0	0.5
Brazil	22443.8	106693.2	84249.5	7.3	170.9	263.9	93.0	22.5
Mexico	10261.1	30725.4	20464.3	1.8	98.0	103.9	5.9	1.4
Rest LAC	24540.6	63790.3	39249.7	3.4	179.8	213.4	33.6	8.1
Africa	55189.4	158786.1	103596.7	9.0	1058.4	1145.0	86.6	21.0
European Union	159401.6	233069.5	73667.9	6.4	210.2	191.7	-18.5	-4.5
USA+Canada	112424.1	221948.0	109523.9	9.5	509.5	475.6	-33.9	-8.2
Australia+New Zealand	16450.6	32586.8	16136.2	1.4	486.8	449.4	-37.4	-9.1
World	738399.0	1886071.6	1147672.6	100.0	4502.6	4915.6	413.0	100.0

Source: Calculated by Authors, from FAOSTAT

LAC represented 32.6% of the world increase in agricultural land during the decades between 1960s-2000s[22], while the share of the increase in world agricultural production during that same period was 14.3%. Therefore, LAC's increase in agricultural and food production and exports, although benefiting from improvements in productivity (see the analysis below), was also associated with an important expansion of agricultural area based on land-use changes that may be difficult to repeat in the future. The increase in agricultural land happened mostly in Brazil and the rest of LAC, while Mexico and Argentina experienced far smaller expansions. In Argentina there has been a significant switch from pastures to crop land (not shown here), basically within the same area. It should be noted the important

[22] LAC's agricultural area expanded in 134.5 million hectares, or 32.6% of the global increase in agricultural area of 413.0 million hectares.

increase in agricultural area in China (about 42%) that exceeded its share of the incremental production (30%), while in India there is practically no change in the share of land use (less than 1%), compared to almost 11% share in the increase in agricultural production[23]. Africa and the Rest of Asia (without China, India and Japan) also increased land use more than the share of production, while in industrialized countries there have been reductions in area with expansions of production, indicating sustained improvements in productivity.

Next Table 11 shows indicators of inputs (fertilizers) and machinery (tractors) using data from the World Bank. The region shows lower levels of fertilizer use per hectare of arable land when compared to the industrialized countries, but also in comparison to China (with a volume of fertilizer use that suggests excess use), India, and South Asia in general. But there are differences between Brazil and the average for the Rest of LAC, which show numbers above the US and the average for High Income OECD countries, while Mexico and particularly Argentina (which enjoys the natural fertility of the Pampas), with clearly smaller levels of fertilizer use.[24]

Regarding machinery, LAC countries are also lagging the industrialized world in tractors per arable land, but the indicator is now broadly comparable with that of other developing (Table 11).

Table 11. Fertilizer consumption and Tractors (average 2000s)

	Fertilizer consumption (kilograms per hectare of arable land)	Tractors (per 100 sq. km of arable land)
World	117.0	na
High income: OECD	120.7	420
European Union	156.4	751

[23] An approximate index of relative land productivity would be to divide the share increase in production by the share increase in land. A number less than one would indicate that the expansion of production has been proportionally more based on land expansion than increases in productivity.

[24] As it was done for land use and production, it would be interesting to compare LAC's and the worlds' performances regarding the increased use of fertilizer and the expansion of production. However, the World Bank time series on fertilizers cover only some years in the 2000s, therefore that comparison cannot be done with the data available. On the other hand, aggregated data from FAOSTAT shows aggregate consumption in metric tons of all type of fertilizers from the 1960s but only until 2002. After that it has a more detailed disaggregation by type of nutrient utilized that cannot be reconciled with the previous numbers. However, taking the aggregate data, the consumption of fertilizers of LAC represented about 12% of the world's total volume increase in the use of fertilizers since the 1960s and until 2002; and using the disaggregated data, and projecting growth for the aggregate for the rest of the 2000s, the share in the increase for LAC would be 13.5% (a very rough estimate, considering the difference in the quality and aggregation of the data). Therefore, LAC's share in the global increase in the use of fertilizers for the 2000s compared to the 1960s is about the same as the share in the increase in the value of production (14.3%).

USA	117.3	267
East Asia & Pacific (developing only)	Na	na
China	420.1	82
South Asia	133.3	121
India	131.7	129
Europe & Central Asia (developing only)	30.8	116
Middle East & North Africa (developing only)	90.4	156
Sub-Saharan Africa (developing only)	11.4	na
Latin America & Caribbean (developing only)	107.8	na
Argentina	40.4	88
Brazil	151.7	133
Mexico	62.7	103
Rest of LAC 1/	162.7	134
1/ Simple average of countries with data		

Source: Calculated by Authors, from World Bank WDI.

Irrigation is another important enhancer of productivity. Table 12 shows the area equipped for irrigation in LAC compared to the world. Although irrigation has increased since the 1960s more than the world average (54% against 45%) still the area irrigated in LAC is 3% of total agricultural area, compared to 6% for the world as a whole.

Table 12. Irrigation (in 1000 ha)

	Area with Irrigation (1000 ha)		
	2000s	Increase 1960s-2000s	% Increase

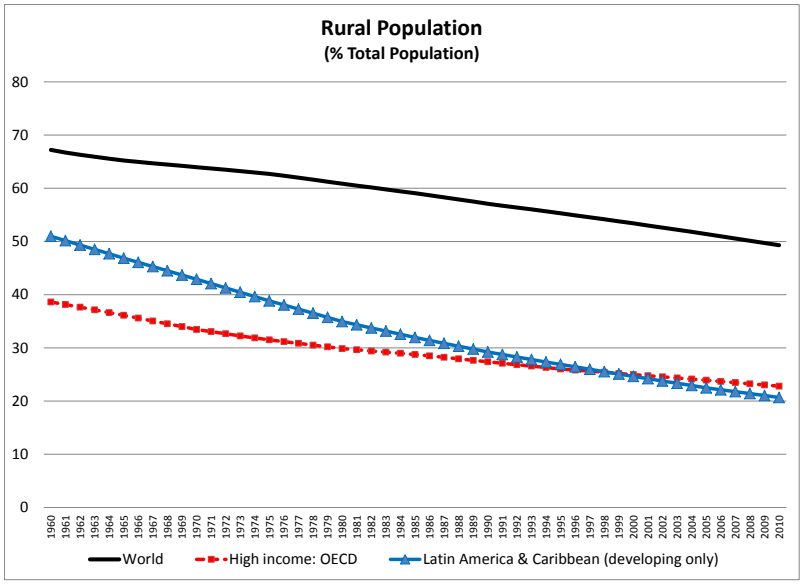
LAC	19830	10793	54%
Argentina	1601	489	31%
Brazil	3973	3361	85%
Mexico	6300	3083	49%
Rest of LAC	7956	3861	49%
World	301018	135898	45%
LAC/World	7%	8%	
Percentage irrigated/total		**2000s**	
LAC		3%	
World		6%	

Source: Calculated by Authors, from FAOSTAT

Another important productive aspect is the use of biotechnology. Here the region shows more advances than other regions. Out of the 29 countries producing GM crops, 10 are in the region. Within the total of about 160 million hectares with GM crops in 2011, after US with about 69 million hectares (43%), the next two countries are Brazil (30.3 million hectares or 19%) and Argentina (23.7 million hectares or 15%). Also Paraguay (2.8 million hectares) and Uruguay (1.3 million hectares) appear in the top ten countries with more than 1 million hectares of GM crops (James, 2011).

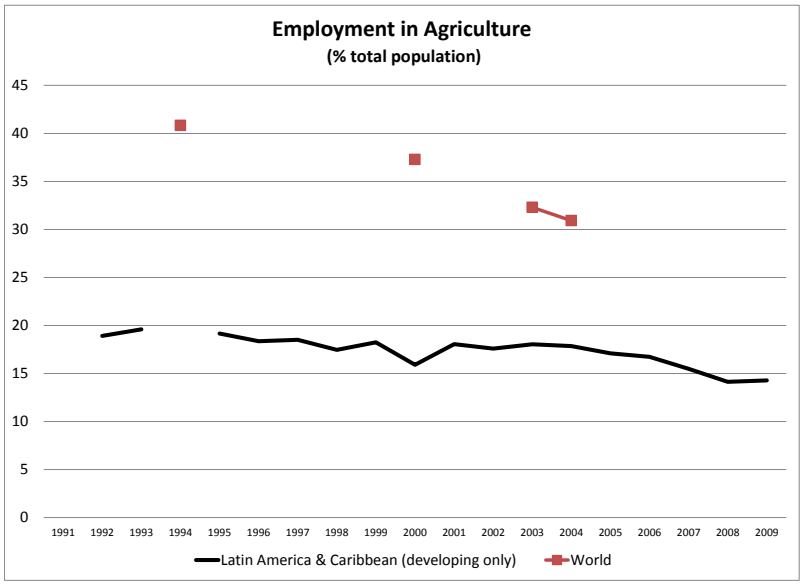
The next two Figures (11 y 12) show changes in rural population and employment in agriculture, in LAC and the world. Both indicators show that LAC has far smaller levels of employment and rural population than the world average. The fact that it has expanded land area but reduced employment in agriculture is reflected in the differential productivity levels for land and labor, as discussed below.

Figure 9. Rural Population (% Total Population)



Source: Calculated by Authors, from World Bank, WDI

Figure 10. Employment in Agriculture (% Total Population)



Source: Calculated by Authors, from World Bank, WDI

4.5 PRODUCTIVITY AND R&D

4.5.1 TRENDS IN PRODUCTIVITY [25]

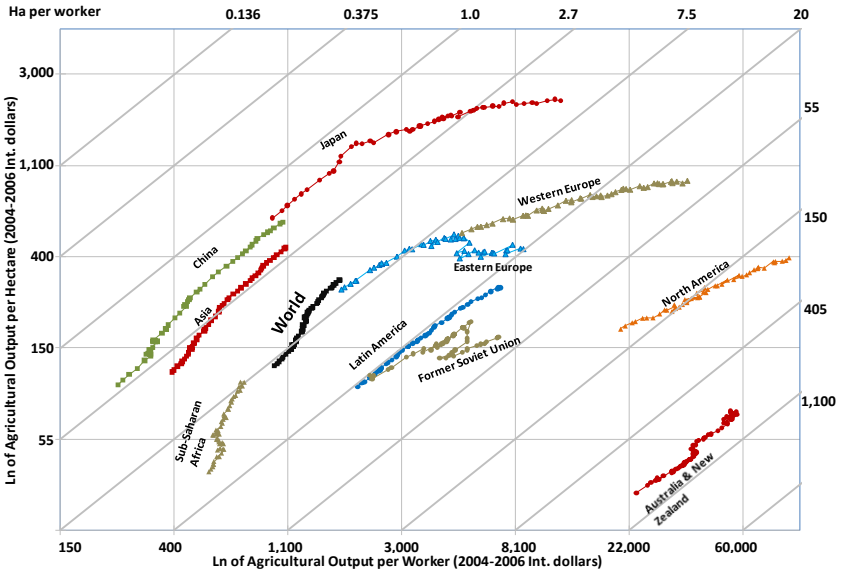
Figure 11 shows the evolution of the agricultural productivity per hectare and per unit of labor since the 1960s (measured in 2004-2006 international dollars[26]), and where is LAC positioned compared to other regions and the world as a whole.. The Chart shows that LAC moved from an output per worker of $2020 and per hectare of $97 in 1961, to $7477 (per worker) and $296 (per hectare) in 2010. Looking at the diagonal lines, it is clear that upward movements in both dimensions have also taken place in most regions (), so the worldwide efficiency in land and labor use has increased on average. But there are clear differences between regions and countries. For example, North America (mostly USA) presents higher levels of productivity of labor than all other regions, but in terms of land is below Western Europe and Japan, and above Australia and New Zealand. Latin America is placed in the middle segment of the Figure. Labor and land productivity are below all developed regions (except for Australia and New Zealand which have lower productivity than LAC in land). At the same time, the region is above world average and above all developing regions (except Eastern Europe) in labor productivity, but only above Sub Saharan Africa and countries of the Former Soviet Union when considering land productivity.

If instead of looking at productivity in levels we consider growth rates (Table 13), the region is below world averages in, both, land and labor productivity increases. In the case of labor productivity, world growth rates were 1.67% and 1.81% in the two periods considered, while the same indicator in LAC was growing at 1.31% and 1.57% in the same periods. Regarding land productivity, the region is also below the world growth average in both periods, but it has accelerated (from 0.59% to 1.44% per year) when it declined or was basically stagnant in the rest of the world, and LAC has also had slightly better growth of land productivity than the average for the 157 countries in the lower 80% of the performers.

Figure 11. Agriculture Land and Labor Productivity, 1961-2010 (measured in 2004-2006 international dollars).

[25] This section is directly based on Pardey, 2012

[26] The adjustment to present data in International Dollars has been explained before.



From: Pardey, 2012

Table 13. Land and Labor productivity

Groupings	Land Productivity			Labor Productivity		
	1961-90	1990-10	Difference	1961-90	1990-10	Difference
	Percent per year					
World	1.67	1.51	-0.16	1.67	1.81	0.14
World minus China	1.66	1.49	-0.16	1.66	1.80	0.13
80% (N = 23)	2.06	2.12	0.06	2.69	3.01	0.32
80% minus China	1.99	2.04	0.05	2.71	2.97	0.27
< 80% (N= 157)	1.61	1.42	-0.19	1.52	1.63	0.12
LAC	0.59	1.44	0.85	1.31	1.57	0.27

Source: Pardey, 2012

Another approach to look at the evolution of productivity in the region is to analyze the growth rate of total factor productivity (TFP). The next Table???, adapted from Avila and Evenson (2005), shows TFP growth rates between the 1960s and the early 2000s.

TFP growht rates in LAC (%) Periods 1961/1980 and 1981/2001

	Agriculture		Livestock		Average per Period		Total Average
Region or	1961/1980	1981/2001	1961/1980	1981/2001	1961/1980	1981/2001	1961/2001

Country							
Southern Cone	**1.49**	**3.14**	**0.72**	**2.51**	**1.02**	**2.81**	**1.92**
Argentina	3.08	3.93	0.9	0.43	1.83	2.35	2.09
Brazil	0.38	3	0.71	3.61	0.49	3.22	1.86
Chile	1.08	2.22	0.24	1.87	0.69	2.05	1.37
Paraguay	3.97	-1.01	-0.36	1.29	2.63	-0.3	1.17
Uruguay	1.29	2.02	-0.32	0.53	0.01	0.87	0.44
Andean Countries	**1.11**	**1.71**	**1.73**	**1.92**	**1.41**	**1.81**	**1.61**
Bolívia	1.73	3.14	2.81	1.39	2.3	2.33	2.31
Colômbia	2.01	1.27	0.49	2.24	1.37	1.73	1.55
Ecuador	-0.74	2.24	0.98	2.51	-0.16	2.34	1.09
Peru	-0.83	1.86	1.86	2.14	0.36	1.98	1.17
Venezuela	2.42	0.87	3.41	1.07	3.03	0.99	2.01
Central America	**1.65**	**1.05**	**2.77**	**1.53**	**2.17**	**1.32**	**1.74**
Costa Rica	2.86	2.09	1.1	0.75	1.74	1.19	1.47
El Salvador	1.22	-0.87	1.99	1	1.77	0.32	1.05
Guatemala	3.31	0.53	0.9	-0.28	1.38	-0.08	0.65
Honduras	1.54	-0.39	2.07	1.91	1.91	1.25	1.58
Mexico	1.53	1.43	3.02	1.63	2.26	1.51	1.89
Nicaragua	1.33	-0.7	2.94	1.92	2.25	0.99	1.62
Panama	2.29	-1.33	1.61	1.49	1.93	0.02	0.97
Caribe	**0.74**	**-2.05**	**1.2**	**0.64**	**0.98**	**0.29**	**0.64**
Cuba	0.88	-2.88	-0.26	-1.03	0.12	-1.69	-0.78
Rep. Dominicana	0.99	-1.15	1.88	2.6	1.62	0.89	1.25
Haiti	0.6	-1.04	3.44	1.8	2.73	1	1.87
Jamaica	-0.65	1.32	3.28	-0.35	2.07	0.29	1.18
Trinidad e Tobago	-0.88	0.16	3	-1.39	1.8	-0.8	0.5
Average %	1.45	2.26	1.39	2.13	1.36	2.24	1.8
ASIA	1.71	2.02	2.2	3.45	1.92	2.5	2.21
AFRICA	1.03	1.74	1.49	1.09	1.2	1.68	1.44
From: Avila and Evenson, 2005							

The first point to be noticed is the large dispersion in TFP growth rates, from Argentina, Bolivia and Venezuela with 2% or more, to the negative value in Cuba and the low growth rates in Guatemala, Uruguay and Trinidad and Tobago, among others. The second point is that for almost every period and product, average TFP in LAC was below the average for Asia and above that of Africa (these regions include only developing countries). At the same time, TFP growth rates for individual countries in those developing regions (not shown here; see the more detailed tables in Avila and Evenson, 2005), indicate

that there were several cases with rates above the best performers in LAC, such as India, China and Malaysia, in Asia, and Mauritania, Benin, Nigeria and Tunisia in Africa, among others.

Those numbers reinforce the idea that LAC's productivity, on average, has been in the middle range for the world as a whole.

4.5.2 INVESTMENTS IN R&D

The productivity trends discussed in the previous section are related to the level of investment in R&D in LAC, which has also been in the middle ranges at the global level. During 1970-2005, public spending on R&D in agriculture went from 11.4 to 28.7 billion dollars (Figure 13). [27] But during that period the rate of growth of public sector funding for R&D in food and agriculture in LAC was below that of low and middle income countries and OECD countries for most of the period, although it has increased somewhat in the 2000s (Figure 12). Therefore, while in 1970, 15% of global spending was concentrated in LAC, in 2005, although total spending went up in the region, LAC's global share decreased to 11% (Figure 13).

Figure 12. Growth in Food and Agricultural R&D Expenditures

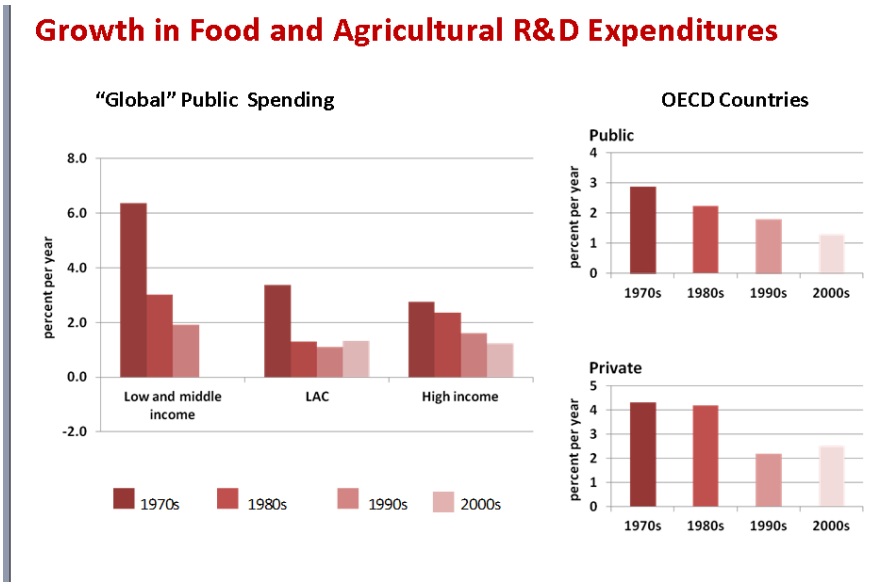
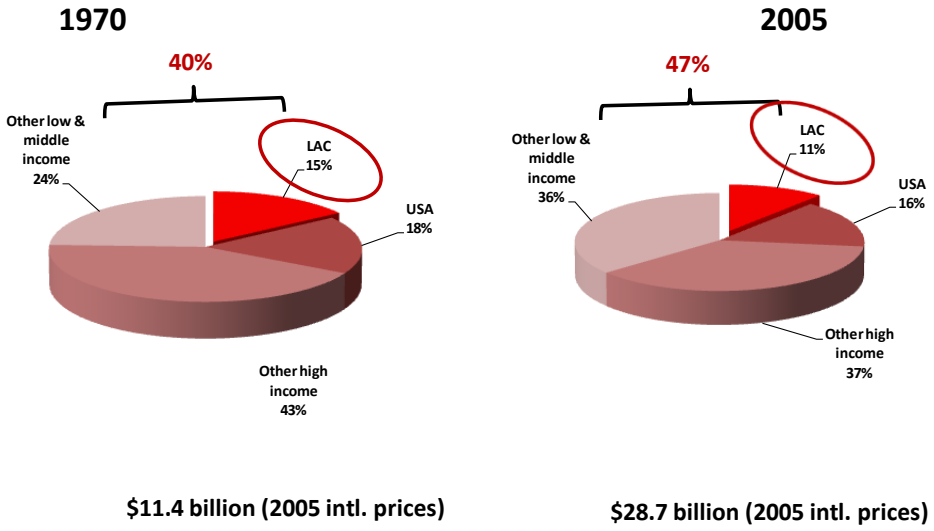


Figure 13. Public Agricultural R&D Spending Worldwide, 1970 vs 2005

[27] Data on R&D expenditures is currently being extended to include private sector statistics, which will provide a better view of the current situation.

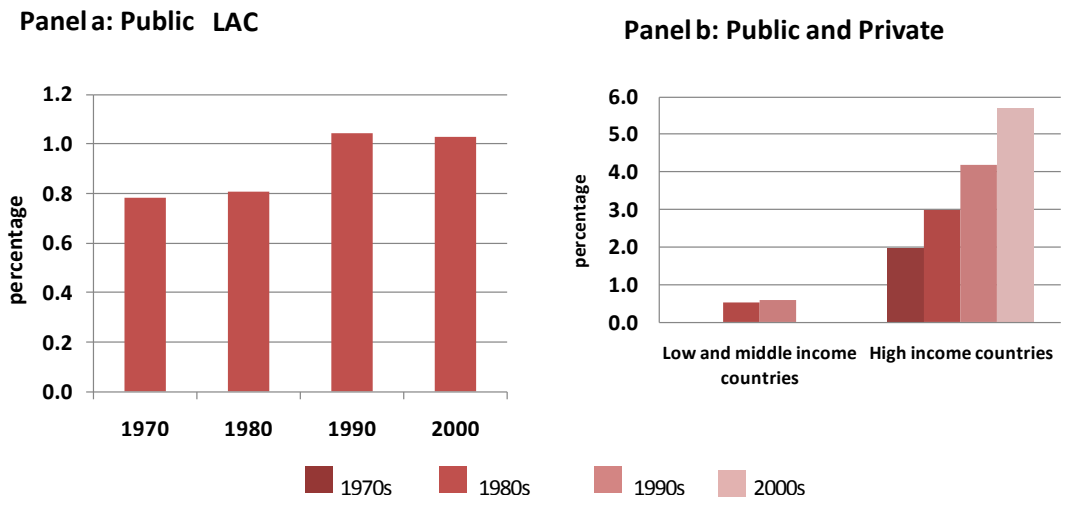


Source: Pardey, 2012.

In addition to rates of growth of expenditures it is also useful to consider the ratio to the value of agricultural production (i.e. expenditures in R&D over the value of agricultural production or the intensity of R&D)[28] (seeFigure 14).

Figure 14. Food and Agricultural Research Intensity Ratios, 1970-2005

[28] As any indicator, the intensity of R&D has its problems of interpretation, starting with the fact that it may increase not because R&D has gone up but because agricultural GDP has gone down ((Beintema et al, 2012), Therefore, its use has always to consider the reasons behind changes.



Source: Pardey, 2012.

The research intensity in LAC has marginally improved in the 1990s and mid-2000s (from 0.8% to somewhat more than 1%). That ratio corresponds to public expenditures only. The second panel in Figure 14 shows public and private expenditures: in high income countries the ratio has been growing every decade, reaching more than 5% against the about 1% in LAC (although the latter considers only public expenditures). On the other hand, LAC shows better ratios of R&D intensity than the average for developing countries (see Panel b in Figure 14).

More recent data in the ASTI Global Assessment of Agricultural R&D Spending (Beintema et al, 2012) calculates that in 2008, total global public spending on agricultural R&D amounted to about $31.7 billion in inflation-adjusted, purchasing power parity (PPP) dollars, divided about equally between industrialized and developing countries. Those numbers represent an increase of about 22% in global expenditures during the last decade when compared to the 1990s, but much of the growth was explained by a handful of countries: R&D spending by China and India accounted for about half of the global increase during; other middle-income developing countries, such as Argentina, Brazil, Iran, Nigeria, and Russia, also contributed significantly to that growth. During 2000-2008 LAC posted the largest growth rate in R&D expenditures since the 1980s (about 2.1% against 1.5% in the 1980s and 1.2% in the 1990s; see Figure 3 in Bientema et al, 2012). However, that growth rate for the region as a whole was the lowest of all developing regions during 2000-2008 (other regions ranged from 2.3% to 8.6%; see same Figure 3 in Bientema et al, 2012). Therefore, LAC's global share, at about 10% of the total, is lower than the number reported before for 2005 (although data may not be completely comparable). Within that 10%,

Brazil amounts to 4% of global R&D expenditures, while the rest of LAC spends about 6% of the world total.

Still, as noted before LAC has the largest intensity ratio of developing regions (somewhat above 1%) although it declined somewhat in 2008 compared to 2000 (Beintema et al, 2012).

The level of patenting and publications in LAC is also lower than that of developed countries and even some developing countries like China (Figure 15 and

Figure 16).

Figure 15. Genetics and Genomics Patents (Health and Agriculture)

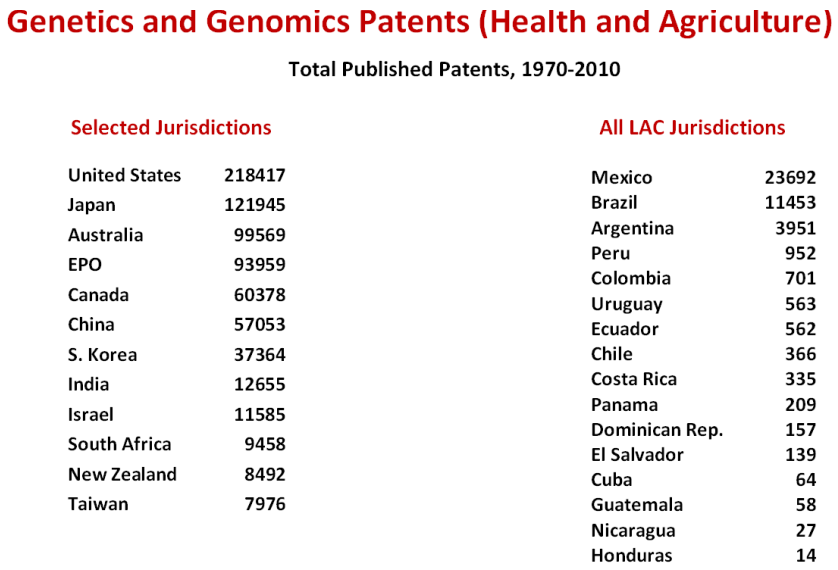
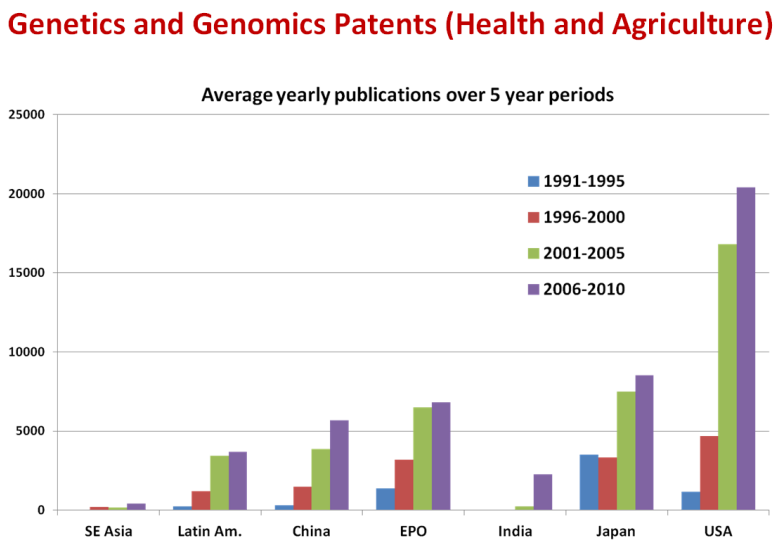


Figure 16. Genetics and Genomics Patents (Health and Agriculture)



Source: Pardey, 2012.

4.5.3 SOME INSTITUTIONAL ASPECTS[29]

The institutional structure for agricultural R&D in the region underwent important changes during the last decades. LAC started during the late 1950s, earlier than other developing regions, with the creation in the public sector of national agricultural research institutes (NARs).[30] They were coordinated mostly by the Ministries of Agriculture and their objective was to increase agricultural productivity and supply, basically by doing adaptive research of technologies developed by the public sector in industrialized countries and promoting the local adoption of those imported technologies. Since the 1960s and 1970s, the region has also hosted three of the international centers of the CGIAR system: the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) created in 1966 in Mexico, the Centro Internacional de Agricultura Tropical (CIAT) created in 1967, and the Centro Internacional de la Papa (CIP) created in 1970 in Peru.

In the 1980s and 1990s macroeconomic crises led to important changes in agricultural policies in the LAC, with the dismantling of supporting services that provided key inputs such as seeds, credit,

[29] This section is mainly based on Trigo 2012.

[30] The first NARI was Argentina's Instituto Nacional de Tecnología Agropecuaria (INTA) created in 1956. Also later during the 1950s Ecuador and Venezuela created their Institutes. After that most LAC countries created NARIs as follows: Mexico (1960), Colombia (1963), Chile (1964), Guatemala (1972), Brazil (1972), Bolivia (1975), Panama (1975), Uruguay (1989), Paraguay (1992), El Salvador (1993), Nicaragua (1993) and Costa Rica (2001) (see Trigo, 2012).

marketing. The NARIs began to focus more on small farmers and poverty issues while moving at the same time towards broader approaches such as "rural development," where agricultural R&D became just a component of a larger approach, along with extension services, provision of rural infrastructure, access to markets, education, etc.

Over time a complex regional institutional framework has developed in LAC, which includes in addition to the NARIs and the CGIAR centers, Cooperation Programs, such as the PROCIs (PROCISUR, PROCIANDINO, PROCITROPICOS, SICTA, PROMECAFE, PROCICARIBE, and PROCINORTE), FORAGRO with IICA as its Secretariat; regional centers such CATIE and CARDI; FONTAGRO (Regional Fund for Agricultural Technology); and technical and financial cooperation organizations of developed countries.

More recently, the private sector – from multinational companies to producer associations – and civil society have also taken up active roles in the development and diffusion of agricultural technology,[31] while at the same time new public actors (such as Universities) have emerged. In several cases, these private sector initiatives helped develop new products or strengthen the competitiveness of traditional ones, with limited or no participation from the public sector.

The previous brief sketch of institutional developments must recognize that there are large differences across countries. For instance, Sain and Ardila, 2009 classified countries in the region using two indices, one that tries to capture a country's ability to innovate and another that focus on the capacity to adapt technological innovations that come from others countries. Each index is based on two variables as follows, which are categorized into five segments:

1. "Innovation Capital Index", which includes a) he number of researchers per unit of area and b) public R&D investment as percentage of Gross Agricultural Domestic Product; and

2. "Imitation Capital Index" which includes a) the schooling level of male workers; b) and number of extensionists per unit of area.

The categorization of the countries is shown in Table ???. The different profiles should be considered to design appropriate strategies for technological development in each country.

Generation/utilization capacity	Description	Countries
High	Countries that have high capacity to generate technological spillovers; and they also have high capacity to appropriate technological spillovers from outside.	1. Brazil 2. Argentina 3. México 4. Chile

[31] See, for instance, Byerlee D., and Echeverría R. (2002).

Medium	Countries that have low capacity to generate technological spillovers; but they have a good ability to take advantage of other technological spillovers that come from outside.	1. Venezuela 2. Cuba 3. Colombia 4. Uruguay 5. Costa Rica 6. Peru 7. Panamá 8. Jamaica 9. Ecuador
Low	Countries that have low capacity to generate technological spillover; and they also have low ability to use the available technological spillovers from abroad.	1. Bolivia 2. Honduras 3. Guatemala 4. El Salvador 5. Nicaragua 6. Paraguay 7. Dominican Republic 8. Haiti 9. Belize 10. Other Caribbean's countries

Given the disparities, it is crucial to strength the link among countries in the region that have different abilities to create and adopt agricultural technological innovations. Therefore, regional cooperation networks (such as FONTAGRO and others) become important tools.

The recent ASTI assessment (Bientema, 2012) also noted a variety of human capacity challenges including older average age of scientists (which may be approaching retirement without a clear line of succession, a problem that affects LAC); the expansion of staff may have been based on inexperienced scientists (bachelor's or equivalent degrees), who lack mentoring and in-country postgraduate training opportunities; there are low levels of female participation in agricultural R&D; low salaries and uncompetitive conditions of service in public agricultural R&D have led to high staff turnover and "brain drain" to the private sector, CGIAR, or abroad. Beintema et al (2012) also highlight the lack of a critical mass of well-qualified researchers in small countries, which underscores the need for regional initiatives that can help them to better use limited resources and avoid duplications.

Currently, different ongoing changes in basic and applied science, in institutions and policies, and in the objectives that agricultural R&D should focus on, are changing the setting where NARIs must operate. These aspects will be discussed later in the Strategic Dimension devoted to technology.

4.6 DEFORESTATION AND GHG EMISSIONS

The increases in LAC's agricultural land discussed before have been accompanied by a decline in the forest area in the region (**Error! Reference source not found.**). LAC lost almost 9% of its forest between 1990 and 2010, while the world lost about 3%. Therefore, the region represents about 2/3 of all the forest lost at the world level during that period.

Table 14. Forest Area (Million Hectares)

	1990	2010	Lost forest (million ha)	Lost forest as % of total forest in 1990
World	4158.2	4020.4	-137.8	3.3
LAC	1038.9	946.0	-92.9	8.9
LAC as % World lost forest area	25.0	23.5	67.4	

Source: Calculated by authors, from FAOSTAT and World Bank

Not surprisingly then, and although LAC has comparatively low levels of GHG emissions (particularly when measured per unit of GDP at PPP)[32], land-use changes and forestry (LUCF) and agriculture represent important components of GHG emissions in LAC.[33] For the world as a whole, LUCF emissions amounted to 17% of global greenhouse gas emissions in 2004 and Agriculture emissions represented 14% (EPA, accessed 2012, http://epa.gov/climatechange/ghgemissions/global.html). But for LAC, LUCF emissions represent the largest percentage of GHG emissions: 46%, compared to 17% for the world, and 30% for developing countries (World Bank, 2009). Houghton (2008) estimated that the region represented 41% of LUCF emissions at the world level (data for 2005).

According to World Bank (2009) the main source of land-use emissions in the region is Brazil, representing about 58% of LAC's total. But as Vosti et al (2011) noted, the percentage contribution of forest clearing to total agricultural GHG may be significant within other countries or regions, like in Central America and the Caribbean where LUCF represents 60% of the emissions from those countries.

[32] LAC has 0.3 kg of CO2-equivalent emissions per 2005 $GDP measured in PPP, compared to 0.7 kg for all developing countries and 0.5 kg for the world as a whole (average for the 2000s from World Development Indicators, World Bank).

[33] Greenhouse gas emissions from agriculture result mainly from the management of agricultural soils, livestock, rice production, and biomass burning. LUCF greenhouse gas emissions primarily include carbon dioxide (CO2) emissions from deforestation, land clearing for agriculture, and fires or decay of peat soils; it does not include the CO2 that ecosystems remove from the atmosphere.

The share of GHG emissions from LAC related to agriculture (as separate from LUCF) compared to world emissions from the sector amounted to about 15.5% of the total (based on 9 countries (data from CAIT, 2005).[34]

In summary, even though LAC's total emissions are globally less important than those from other developed and developing regions, LUCF and agriculture have a large incidence both within the region, and for the world as a whole in those categories.

4.7 OTHER POLICY AND SOCIO-ECONOMIC DEVELOPMENTS

The developments discussed in the previous sections took place in the context of other policy and socio-economic developments that are briefly reviewed here.

4.7.1 POLICY DEVELOPMENTS AFFECTING AGRICULTURE[35]

Agricultural policies as well as the general matrix of macroeconomic and trade policies, which together determine the net effect on the agricultural sector of developing countries, have been changing over time in the world and in LAC.

During the 1950s and 1960s, the development strategy considered the role of agriculture as subordinated to the needs of industrialization, within what has been called Import Substitution Industrialization (ISI). Different arguments were utilized to support this view, but in LAC it had special influence Prebisch's view about deteriorating terms of trade and the need to diversify the economic structure out of agriculture and into industry (Cepal, 1969). Within the ISI approach the nuts and bolts of agricultural policies were based mostly on the use of administered prices at different stages of the market chain; the existence of public and parastatal enterprises operating in product and input markets, in good measure to enforce the administered prices, but also to ensure the supply of some inputs; and the establishment of public agricultural banks and the supply of subsidized credit. In many cases those policies tried to help what was considered to be "modern" and more productive units.

The issue of poverty in rural areas was mainly addressed through community development and land reform (the latter topic will be discussed below in another section).

Both the overall development strategy and agriculture's role within it, as well as sectoral policies began to be reviewed in the mid 1960s and early 1970s, when different concerns arose about the adequacy of a development strategy that concentrated savings and investment in industrial development and

[34] The countries are Argentina, Bolivia, Brazil, Chile, Colombia, Mexico, Peru, Uruguay, and Venezuela. The CAIT data is being updated and these numbers are tentative.

[35] This section is based on Orden and Diaz-Bonilla, 2006.

discriminated against the agricultural sector. Within the agricultural sector, policies began to emphasizes technological solutions to the rural problem leading to the Green Revolution of the 1970s. This approach led to the creation of the system of international research centers (the CGIAR) and of national agricultural research institutes and extension services in many developing countries during the 1960s and 1970s. Another argument emphasizing the importance of agriculture in the development process was provided by the realization that the poor in developing countries were concentrated mainly in rural areas. If poverty alleviation was to be an important objective of economic policy, then greater attention should be given to agricultural and rural development. These ideas led to broader programs in rural areas specially targeted to reach low-income groups in what was called "Integrated Rural Development."

While highlighting the importance of agriculture, both the Green Revolution and the Integrated Rural Development approaches were undertaken within the framework of development and macroeconomic policies still shaped by ISI. Other analyses (such as Little et al. (1970) and Balassa et al. (1971)) were critical of that overall approach, and called for a modification of the import-substitution approach that protected industry and the elimination of policy biases against exports, including agriculture. They highlighted the negative impacts on growth and poverty alleviation of the structure of "macro prices" enforced through governmental policies. Thus, poverty problems could not be resolved simply by restructuring micro-policies or by reallocating investments to the poor.

At the sectoral level, one of the characteristics of the interventions of the 1960s and 1970s was the granting of preferential loans in many developing countries through sectorally specialized institutions (industrial as well as agricultural and rural banks). The expansion of credit was commonly financed through rediscounts from the Central Bank or similar institutions, which expanded money supply, basically in the context of closed capital accounts. This approach was criticized at the macro level for contributing to inflation, and at the micro level because subsidized agricultural credit generated a misallocation of resources in the rural sector (excessive capital intensity and land speculation), did not reach the poorest sectors because preferential credit was absorbed by the largest farms, and discouraged rural savings and the development of rural financial institutions and markets.

The two oil shocks of the 1970s and the change in macroeconomic policies in industrialized countries in the early 1980's (with sharp increases in real interest rates and the subsequent recession) affected severely many developing countries and led to the debt crisis of the 1980s, mostly in LAC and Africa. Agricultural prices collapsed in the mid 1980s, primarily as a result of those macroeconomic changes and expanded public support of agricultural production in industrialized countries, particularly as the EU increased subsidization of exports and the reforms in the U.S. reduced other price-support mechanisms. The agricultural transformation in China, the expansion of the Green Revolution in many developing countries, and the break-up of the Soviet Union, were developments that added to global

agricultural supplies and/or weakened demand within agricultural markets, exacerbating the collapse in prices. The possibility of financing import substitution industrialization with the rents extracted from agriculture basically disappeared, leading to the progressive reduction of taxes (and of price schemes with similar effects) on agricultural export goods.

More than the analytical studies showing the economic limitations of ISI, what prompted the change in overall development strategies in the 1980s was this sequence of macroeconomic shocks and the ensuing debt problem.

The Development Report of the World Bank in 1986, which focused on agriculture, codified these lines of analysis into several policy recommendations: developing countries should eliminate inefficient industrial protectionism; correct the overvaluation of the exchange rate; eliminate export taxes on agriculture; reduce government's involvement in agricultural markets; and phase out administered prices, public sector enterprises operating in output and input markets, and state-owned agricultural banks and directed agricultural credit schemes. Budgetary savings from the elimination of public interventions, which were considered inefficient, contradictory, and open to waste and corruption, could be reassigned to investments in technology, extension and training, and infrastructure. General and sectoral "structural adjustment programs" by the World Bank and other international banks and donors, financed the implementation of those policy changes in many developing countries.

Within the new general framework, the poor, particularly in rural areas, were supposed to benefit from more sustainable growth, once the capital-intensive and anti-agricultural development strategy was corrected. The remaining poor could then be aided through focused policies. The "basic needs" approach that had emerged in the late 1970s provided a possible rationale for this reorientation and focalization of social services in the 1980s.

Macroeconomic and trade policy changes in developing countries during the 1980s and 1990s led to depreciated real exchange rates (RER) and reduced overall trade protection (see Orden and Diaz-Bonilla, 2006). Jensen, Robinson, and Tarp (2002) calculated that whatever anti-agriculture bias existed as a result of trade and macroeconomic policies in the 1960s and 1970s in developing countries (as studied in Krueger, Schiff, and Valdés, 1988), was largely eliminated during the 1990s.

At the same time that price distortions were reduced or eliminated, the decline in agricultural world prices and other developments were moving against the agricultural sector. At least in LAC and SSA growth declined significantly during the 1980s and 1990s, affecting demand for agricultural goods. Overall fiscal position of developing countries deteriorated during the 1980s, which along with the decline in world agricultural prices in the mid-1980s, led to fiscal adjustments and pressures to reduce support for agriculture in many countries.

Credit conditions also changed. During the 1980s, and then more markedly in the 1990s, many developing countries, began to open up their capital accounts, expecting beneficial impacts on growth, efficiency, and smoothing of volatility. This changed the context for monetary policies, making more difficult to manage the objective of stable exchange rates and open capital accounts, while pursuing an independent monetary policy. At the same time the IMF, World Bank and other international organizations as part of the structural adjustment and stabilization programs of the mid-1980s and 1990s supported financial sector reforms, including changes in the public sector agricultural agencies such as agricultural banks and parastatal companies that, among other things, provided credit to farmers. Some of the reforms, while eliminating many of the inefficient and contradictory public sector interventions, also dismantled the institutional infrastructure that provided technical assistance and some key inputs to agricultural production (including credit, seeds and fertilizers), and marketing services, without ensuring the creation of private sector institutions that could provide similar services and inputs.[36]

In the international economy, the Uruguay Round concluded in the mid-1990s helped revert in part the high levels of support and subsidization in developed countries. At the same time, there was an expansion of international capital flows that led to a more volatile economic environment for developing countries, with the sequence of crises in Mexico in 1995, Asia in 1997, Russia in 1998, Brazil in 1999, and Argentina in 2001. Prices of commodities collapsed in the late 1990s and early 2000s.

In terms of poverty alleviation, in the second half of the 1990s a new type program called cash-transfers began to be implemented in several LAC countries. Although the details vary, they basically consist in income transfers given mostly to heads of households (mainly women), with specific requirements related to attendance at school and health check-ups for their children. Those programs appear to have had positive impacts on local activity and short-term growth, and on accumulation of physical capital and formation of human capital.

During the 2000s strong global growth, fuelled by developing countries and biofuel mandates, among other things, changed the context for agricultural commodities, whose prices began to rise from the bottom early in the decade, and eventually led to the price shocks of the late 2000s. Instead of the concerns about low prices on the 1990s, agricultural and social policies shifted to policies aimed at

[36] An important support for investments is agricultural credit (see, for instance, Reca, 1969. One of the characteristics of the "developmental state" in many developing countries was the granting of preferential loans through sectorally specialized institutions (industrial as well as agricultural and rural banks). However, market liberalization reforms starting particularly during the 1980s and 1990s eliminated or scaled down those banks (see for instance, de Janvry, Key, and Sadoulet, 1997), which may have led to the decline in agricultural credit, but data is lacking. Some of the estimates of agricultural credit for LAC are old (such as Wenner and Proenza, 1999, but they showed that the un-weighted average ratio of agricultural credit over total credit and as a percentage of agricultural GDP for a number of LAC countries has declined (see the discussion in Diaz-Bonilla and Robinson, 2010).

stabilizing those new high prices and shielding consumers from price shocks. Global imbalances fuelled by another surge of international capital resulted in the current crisis.

Foresight studies must start from this new context.

4.7.2 ECONOMIC AND SOCIAL ACTORS IN AGRICULTURE[37]

Changes in LAC's agricultural production discussed before have taken place against a background of important changes in both agrarian structures (linked to land tenure patterns), and in the organization of the broader value chains (within which land-related issues are just one component).

4.7.2.1 Land Tenure Issues

The dual structure "latifundio-minifundio," with the large inequalities in land tenure and socioeconomic power emanating from it, has been a historical trait of many LAC countries since the colonial period. From time to time it led to peasants' revolts and attempts to reform some of the main inequalities. Before the 1960s there were several important land reforms (Mexico in the 1920s, Bolivia and Guatemala in the early 1950s, and Cuba in the late 1950s), but it was the Alliance for Progress, launched in 1961 that put in motion a larger process of agrarian reform in LAC. Studies conducted by the Comité Interamericano de Desarrollo Agrícola (CIDA), [38] with the participation of FAO, OEA, BID, and ECLAC, y la CEPAL, found large inequalities and concluded that they affected negatively not only employment, poverty, and income distribution in the rural areas,[39] but also led to large inefficiencies and sub-par production because landowners did not have incentives to invest and modernize agriculture, and limited the expansion of the domestic market (landowners were considered to allocate their income to sumptuous consumption usually supplied from abroad and the peasantry did not have enough incomes to generate a vibrant domestic market for the expanding industry). Therefore, the dual land structure imposed heavy costs to LAC's development efforts, and created unequal societies with weak democracies and periodic bouts of violence. Concerns about the possibility of the expansion of the Cuban revolution to other LAC countries were always present.

During the next decades several countries in LAC implemented agrarian reforms: Chile, from mid-1960s to mid-1970s, Peru during the 1970s, and Nicaragua and El Salvador in the 1980s (FAO 2012). These reforms (which whatever the level of land redistribution achieved also led to the

[37] What follows is based mainly on CEPAL, FAO, IICA (2012).

[38] The studies included Argentina (1965), Brazil (1966), Colombia (1966), Chile (1966), Ecuador (1965), Guatemala (1965) y Perú (1966). There were other subsequent analyses (see, Barraclough and Collarte, 1971).

[39] Other studies have also argued that the excess of labor supply coming from the rural areas to urban centers put downward pressures on urban wages, generating further economic inequality.

elimination of social arrangements based on indentured peasants), along with the process of urbanization , the expansion of new agricultural technologies and somewhat improved public agricultural services and rural infrastructure, reduced the pressure of rural movements, and, with the fading threat of a Cuban-like revolution in the region, agrarian reforms were slowed down or stopped. The integration of rural and urban markets and the expansion of exports, also led to the development of new value chains, the emergence of new types of large and medium-sized producers, and the transformation of the traditional peasants. Although tensions around land issues continued, were now also linked to new problems such as guerrilla and drug-related rural violence (CEPAL, FAO, IICA, 2012).

The return of democracy to several LAC countries in the 1980s and 1990s brought slowly again to the public agenda the issue of unequal land tenures, particularly in Brazil, Colombia, Bolivia, Venezuela and Paraguay (CEPAL, FAO, IICA, 2012). For instance, after the return to democracy in the mid-1980s, Brazil has expanded the work on agrarian reform through expropriations, direct purchases, set-aside of public lands and legal recognition of occupied lands, with almost 70 million hectares added to the land area covered by agrarian reform between 1995 and 2010 (CEPAL, FAO, IICA, 2012). Bolivia passed Law No. 3,545 in 1996 that led to about 40 million hectares being regularized, covering some 174,000 persons (CEPAL, FAO, IICA, 2012). Along with these more traditional approaches to agrarian reform, another strategy was to facilitate access through credit to small buyers to purchase land. These were market-based, voluntary land transactions, with the government intervention mainly aimed at ensuring a fair transaction at non-inflated prices. Brazil, Chile, Colombia, Guatemala, El Salvador, Honduras and Mexico are some of the countries that implemented these programs, but the amount of land distributed has been small (CEPAL, FAO, IICA, 2012).

Still, LAC continues to be the region with largest inequalities in land holdings: in late 1990s and early 2000s, the concentration measured by the GINI Coefficient for land holdings in LAC was about 0.82 (the closer to 1 the more concentrated), against 0.53 in Africa, 0.57 in Asia (developing), 0.59 in the European Union, and 0.64 in Canada (Diao, X., Diaz-Bonilla, E., Robinson, S. and Orden, D., 2005). During the last decade the process of concentration seems to have increased further, notwithstanding the efforts at land redistribution mentioned, although the evidence is not clear because many countries have not completed censuses of agriculture since the 1990s, and the information available in agricultural and household surveys, and population censuses is inconclusive (CEPAL, FAO, IICA, 2012).[40] In contrast

[40] For instance, in Paraguay the Gini Index increased from 0.91 in 1991 to 0.93 in 2008. In Chile the 2007 census shows that there were 242000 farms with less than 12 hectares of basic irrigation (HRB in Spanish, is a standardized measure to make land area comparable), while on the other hand 25000 farms with more than 12 HRB controlled 80% of the agricultural land (FAO, 2012; Dirven 2011). Considering production, Ribeiro Vieira Filho, Garcia Gasques, and de Sousa (2011) report that in Brazil, 8% of the farms produced 85% of the value of agricultural production.

with those trends, in Mexico land appears to have subdivided further, with the number of production units increasing from 3.8 million to 4.1 million and the average area of production units declining from 8 hectares to 7.3 hectares between 1991 and 2007 (CEPAL, FAO, IICA, 2012).

Other trends and facts related to land issues include the following (FAO, 2012, and CEPAL, FAO, IICA, 2012):

* Many farms lack title to the land in LAC (about 50%), particularly in the countries of the Caribbean and in the agricultural frontier in Central America and South America, which inhibits investments, closes access to credit, does not allow a proper management of natural resources, and leads to social conflicts and violence.

*There has been an expansion of land buying in the region mainly by regional ("translatinas") firms and local groups expanding into neighboring countries (CEPAL, FAO, IICA, 2012). This process also included some international corporations and wealthy individuals, but the phenomenon of large-scale land buying by foreign governments (which is the more restricted definition of "land grabbing"), does not seem to have happened in the region. However, according some studies, foreign ownership has also expanded (FAO, 2012). Given that compared to other regions LAC has a smaller percentage of land owned by the State, many of those land sales have been private transactions. Also, several of those land deals started before the spike in food prices and seem to have been related to broader reasons than only the food scare (CEPAL, FAO, IICA, 2012)

*Besides land purchases there have been other ways to concentrate production and achieve economies of scale. This is the case of the planting pools in the Southern Cone, and the expansion of contract farming in most LAC countries (FAO, 2012).

*Cross-border movement of agricultural producers, although is a long standing trend in some countries mainly in the Southern Cone, may have strengthened in the last decade or so. For instance, the influx of Brazilian farmers has changed significantly the productive structure of Paraguay, where in some products (such as soybean) the largest participation is from foreign producers, which have followed a productive model with low diversification and environmental costs due to deforestation (livestock and some staple crops such as cassava seem to be the main products where Paraguayan producers are a majority) (Dirven, 2011). It may be happening the same in Bolivia.

*Another trend related to land, but largely exceeding the productive aspects, is the indigenous movements that claim land ownership but as a component of a broader process of establishing an indigenous identity and achieving recognition of special rights and their own internal political processes (CEPAL, FAO, IICA, 2012).

*Other land-related issues include the expansion of cities and other activities such as industry, tourism, and infrastructure that are impinging on farm land, and the new notions about the multiple

functions of land beyond the provision of food and fiber, to include environmental, tourism, recreational, and biodiversity services (CEPAL, FAO, IICA, 2012).

4.7.2.2 Labor Markets

Besides the changes in land structures and other land-related issues there have been other important developments in labor markets of LAC countries. They include (CEPAL, FAO, IICA, 2012):

*The reduction in the importance of agricultural employment. During the last decade the proportion of the rural labor force employed in agriculture decreased in 11 of the 14 countries analyzed in CEPAL, FAO, IICA (2012), although agricultural employment as percentage of rural employment remains above 60% in Bolivia, Brazil, Colombia, Ecuador, Honduras, and Peru (but in other countries such as Costa Rica, Mexico and the Dominican Republic is less that 40%).

*The increase in women employment, but still with a low participation. The increase in employment has taken place particularly in non-agricultural activities, influenced by the increase of these activities, in many cases linked to exports, such as processing of fruits and vegetables (CEPAL, FAO, IICA, 2012). Only in countries where traditional agrarian systems prevail, such as Bolivia, Ecuador, and Peru rural women employment is higher in agriculture (CEPAL, FAO, IICA, 2012).

*Urban residence among agricultural workers has increased during the last decade in 10 out of the 12 countries with comparable data, helped by improved transportation infrastructure (although the definition as "urban" of some population centers is debatable).

*Youth migration to urban centers and the aging of LAC farmers, as part of a broader age increase of LAC population, but with differences between the older populations in the Southern Cone and the younger ones mainly in Central America.

Otherwise, there has been a diversity of trends in the proportion of salaried labor, self-employment, and non-paid family employment, depending on whether it is agricultural employment or non-agricultural rural employment (CEPAL, FAO, IICA, 2012).

4.7.2.3 Agribusiness and Supermarkets

At the level of actors in the agribusiness and marketing space there have also been important changes. International seed companies have expanded in the region providing technology mainly for cereals and oilseeds. Machinery and irrigation companies have also extended their operations in the region. Meat conglomerates have been organizing the value chain through larger-scale operations in beef, poultry, and pork production.

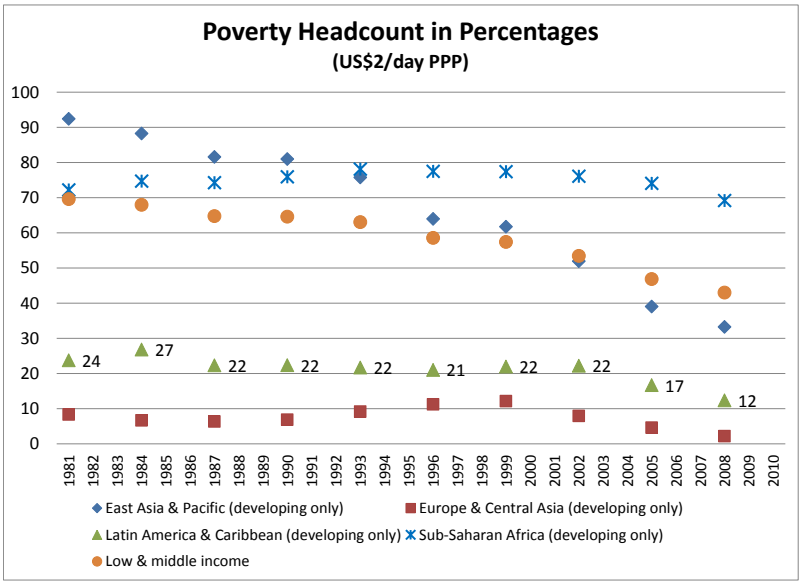
But probably the most important change has been the supermarkets re-structuring the whole food chain, including processed and fresh products, including fruits, vegetables and specialties (Reardon and

Timmer, 2012). LAC is the developing region where the expansion of supermarkets started earlier and has gone further: in the 1990s they were a niche retail market occupied by domestic firms covering about 10-20% of national food retail sales; by 2000 supermarkets had increased to 50-60% of national food retail in many countries in the region, getting in one decade closer to the 70-80% share of the United States that took five decades to reach. Brazil has the highest share, followed by Argentina, Chile, Costa Rica, Colombia and Mexico. The take-over of food retailing has developed faster in processed, dry, and packaged foods (in which economies of scale are important), but fresh products (from potatoes to different types of meats) have also been increasing. Still, the share of supermarkets in fresh foods is about half the share in packaged foods. But for some fresh products, such as fruits and vegetables, supermarkets in Latin America buy about 2.5 times more of those products from local producers than they are exported to world markets. Another point to be noticed is that the expansion of supermarkets has been driven by foreign direct investments: according to some estimates in LAC multinational chains constitute about 70-80% of the top five chains in several countries (Reardon and Berdegué, 2002, and Reardon, Timmer and Berdegue, 2004).

4.7.3 Other Socio-Economic Developments

During the last decades LAC countries also showed other important socio-economic changes (data from World Development Indicators/World Bank, 2012): GDP per capita (in constant dollars) increased by 85% to an average of 8500 dollars per capita (GNI Atlas method) in 2011, while the world as a whole increased by 81%; LAC has an average of about 8500 dollars per capita (GNI Atlas method) in 2011, compared to 3600 dollars for all developing countries, but it is still far below the 39800 dollars per capita of developed countries. The percentage of population suffering from poverty declined from 24% in 1980, to 12% in 2008 (latest World Bank data, using a poverty line of 2 US dollars/day in PPP terms)), a level well below the average for developing countries (Figure 17). At the same time LAC remains the most unequal region of the world: for instance while the average GINI index for 135 countries with data for the 2000s is 40.8 (median 39.7), for the 20 LAC countries with data during the same period the average is 52.2 (median 52.1) (data from World Bank, WDI, 2012).

Figure 17. Poverty Headcount in Percentages (u$s/day PPP)



Source: Calculated by authors, from World Bank

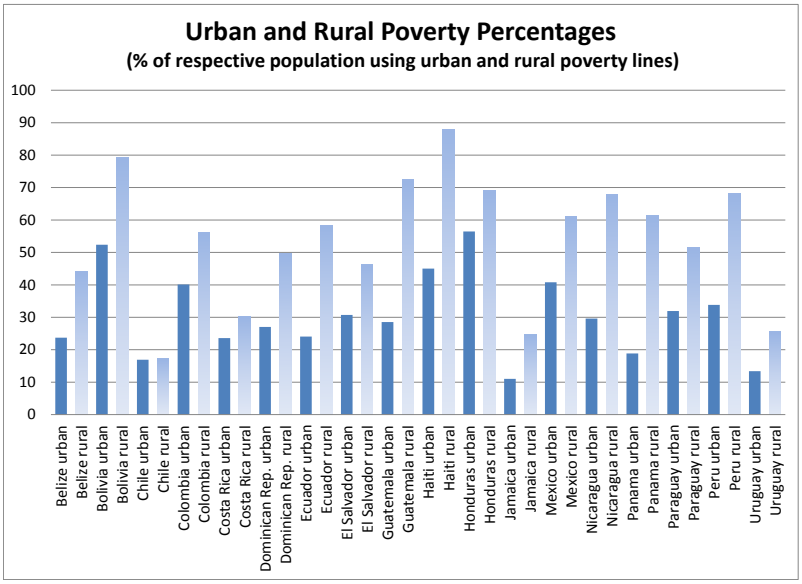
Using different data from CEPAL (see Table…) several facts can be highlighted: first, after increasing in numbers during the first decades, in 2010 there has been a decline in the numbers of total, urban, and rural poor; second, the number of urban poor in the region has exceeded the rural poor in numbers since the 1990s; third, rural poverty has been declining as percentage of total poverty and in 2010 represent only 1/3 of that total.

Poverty in LAC 1/(million of people)				
	Total	Urban	Rural	Rural Poverty as % of Total
1980	144	69	74	51
1990	210	127	83	40
2000	225	144	79	35
2010	193	129	63	33
From Trigo, 2012, using data from CEPALSTAT (2011)				
1/ It includes the following countries: Argentina, Bolivia, Brasil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, México, Nicaragua, Panamá, Paraguay, Perú, República Dominicana, Uruguay, and Venezuela.				

Although poverty in LAC is 2/3 urban, still the incidence of rural poverty among rural population remains clearly above the urban levels (see next Figure 18, for a sample of LAC countries with

differentiated data).[41] The percentages are calculated using a specific country's poverty lines, differentiated by urban and rural. On average, for this sample of countries, rural poverty is about 24 percent points higher than urban (54% to 30%).[42] Also, the incidence of poverty is higher among the indigenous population, and among households which depend on agricultural income or transfers (FAO, CEPAL, IICA, 2012)

Figure 18. Urban and Rural Poverty Percentages



Source: Calculated by authors, from World Bank

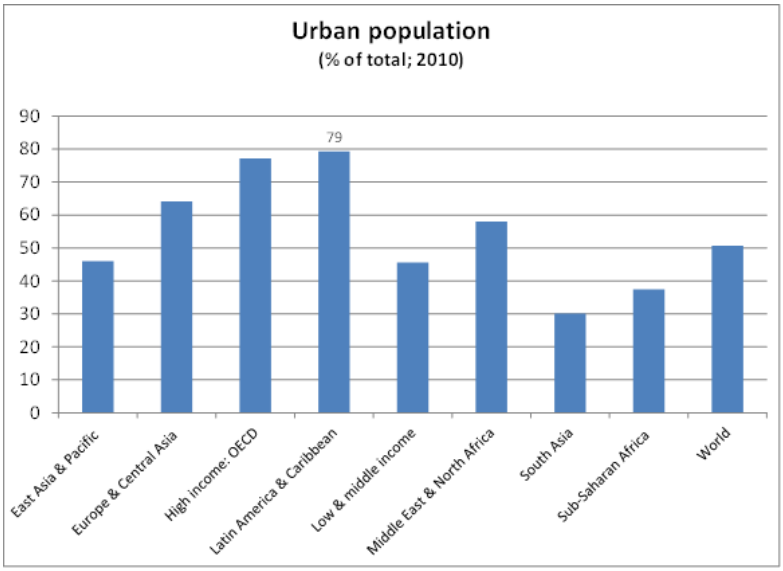
Since the 1960s, the average inhabitant of LAC countries has added 18 years to life expectancy (reaching 74 years at the end of the 2000s) and achieved 91% of literacy (the world added 17 years reaching 70 years of life expectancy, and had an average literacy rate of 83%).

LAC is the most urbanized region in the world (Figure 19), even surpassing recently developed countries' rate of urbanization: the percentage of urban population increased from 53% in the 1960s to 79% in 2010 (changes at the world level were from 34% to about 50% during the same period; current urbanization rate in developed countries is 77%).

[41] It must be emphasized that the percentages of rural poverty incidence are for the headcount of rural poor over rural population, normally using a rural poverty line; similarly, the urban percentages are for the headcount of urban poor over urban population and basically using an urban poverty line. Therefore, they do not represent values over total population (as it was shown before), and cannot necessarily be compared across the rural/urban space.

[42] When compared with the lower poverty rates in the previous Chart it must be remembered that the specific country lines are different from, and higher than, the World Bank's US$2/day at PPP –required to compare across countries- used in the previous Chart. Here the focus is only on the differences between urban and rural within the same country, because data in the Chart does not allow comparisons across countries (which would have required a comparable PPP based indicator).

Figure 19. Urban Population



Source: Calculated by authors, from World Bank

4.8 SOME FINAL COMMENTS

LAC agricultural sector has had a relatively strong performance during the last half a century, outpacing global growth in food availability, with calories per capita in the region rising by 29% and protein by 35% between 1960 and 2009. Meanwhile, the region's agricultural production has increased its share of global output from about 10% in the 1960s to about 13% in the 2000s. On average during the last 10 years, LAC's production (valued in constant terms) has become slightly larger than that of either, the European Union or USA plus Canada, and has exceeded India's total by almost 30%, but it has been less than 60% of China's agricultural production. This increase resulted to a large extent from agricultural expansion in Brazil and also reflects the faster growth of livestock production when compared to crops.

During the 2000s, LAC also became the world's main net food exporting region, reflecting mainly but not exclusively the net trade surpluses generated by Brazil and Argentina. Policy changes related to macroeconomic stabilization and liberalization led to a significant diversification of the agricultural production, which has been reflected in important changes in the structure of exports: the share of traditional tropical products (such as coffee, cocoa, sugar, and textiles) in total exports declined, while that of fruits and vegetables, oilseeds, and meat products increased.

Those gains in LAC's agriculture have been driven in part by productivity improvement, but also resulted from a significant expansion of agricultural area over the last half century. The region has

contributed a third of the global increase in agricultural land (crops and pastures) since the 1960s. LAC also accounted for two-thirds of global deforestation from 1990 to 2010. Unsurprisingly, land-use change contributes more to LAC's greenhouse gas (GHG) emissions than any other source, even though the region's emissions are comparatively lower than other regions. Another worrisome consequence of rapid land-use change is the pressure this places on LAC's globally important reservoirs of biodiversity.

The expansion of LAC's agricultural area, based on land-use changes and deforestation, will be difficult to repeat in the future without affecting climate change and biodiversity.[43]

LAC thus plays a dual role by contributing both to food security and environmental sustainability at the national and global levels. To play that role effectively, R&D activities are and will be crucial. But technological levels vary significantly between and within countries and across the variety of producer groups. During the last decades, agricultural R&D activities and institutions have evolved considerably, starting with the creation of public- sector national agricultural research institutes (NARIs) in the late 1950s, earlier than in other developing regions. Soon afterwards, three of CGIAR's international centers were established in LAC. Over time a regional institutional framework took shape, which included FORAGRO and various sub-regional structures. More recently, the private sector – from multinational companies to producer associations – and civil society have also taken up active roles in the development and diffusion of agricultural technology. Public investment in agricultural R&D has increased somewhat, particularly over the last decade. But LAC's average ratios are well below the levels of developed nations, and a few countries, notably Brazil, account for much of the improvements, as investment has declined in the smaller and poorer countries that are most in need of agricultural R&D.

Those changes in production took place within agrarian structures showing large inequalities in land tenure, with small farms fragmenting further and large landholdings expanding. Conflicts around land tenure continue in several countries. All of this is squeezing out family farms and local communities with traditional production structures and knowledge. There are also important developments in labor markets, with more salaried and less self-employment, the expansion of non-agricultural rural activities, and a differentiated role for women labor, depending on whether production is based on traditional staples or it has evolved to new products, such as fruits and vegetables.

Other actors in agricultural production, processing, and marketing have also seen important shifts, with seed companies providing technology for cereals and oilseeds; meat companies organizing whole

[43] However, in some countries, like Brazil, the previous expansion of agricultural area have had a large component of pastures, which could now be converted into crops, without further affecting forests (beyond those lost when the area was originally cleared for pastures). The possibility of this "internal" expansion within the current agricultural area by converting pastures into crops varies by countries. Where that possibility does not exist, the main point still remains: further expansion of agricultural area (crops plus pastures) that impinges on forests would affect environmental sustainability and biodiversity.

value chains through large-scale production of beef, poultry, and pork; and supermarkets structuring the production of fruits, vegetables, and specialty foods. The agricultural and agroindustrial production processes have been increasingly controlled by large agricultural operators, input companies, agri-industrial processors and supermarket chains.

The agricultural sector operated within a policy context that moved from import substitution, to liberalization, and now it has a more balanced approach across macroeconomic, trade, and agricultural policies. Socio-economic conditions also saw improvements in income per capita and education and health indicators, along with declines in poverty rates, which are clearly better than the levels of developing countries in Asia and Africa. Still, the incidence of poverty in rural areas is larger than in the cities, but because LAC countries have become the most urbanized in the world, the greatest concentration of poverty occurs in urban centers in the region, as rural populations and agricultural employment have fallen significantly. At the same time, LAC shows some of the highest levels of inequality of the world, which starts with large inequalities in land tenure.

Meanwhile, democracy expanded in LAC during the last decades, which is now the developing region with the largest percentage of countries under broadly democratic regimes.

In order to imagine future scenarios for LAC's agriculture it is important to keep in mind the evolution of these last decades. The previous historical overview shows that LAC faces complex challenges for agricultural development and the related R&D activities. The trade-offs mentioned between contributing to global, regional, and national food security and environmental public goods involve multiple dimensions. Therefore, agricultural R&D in LAC must include, but also go beyond, a limited focus on staple crops produced mainly by small and family farms if the most pressing issues for food security and environmental sustainability playing out in the region are to be addressed.

5 STRATEGIC DIMENSIONS AND TRENDS

The construction of future scenarios for agricultural production and food security must consider several strategic dimensions, drivers and trends. Two basic factors are income or GDP growth, and population growth. During the last decades, the economic and demographic evolution has taken place within an increased integration of the world economy (what has been called economic globalization[44]). The consideration of global trade, financial, and macroeconomic developments are central in that regard. On the demand side of food products, the process of urbanization and changes in consumption habits and values are significant factors to be considered in any projection. Another group of factors relate to the price and availability of energy, of which the issue of biofuels and bioenergy is only one component, and

[44] See Diaz-Bonilla and Robinson, 2001 for the different components of the concept of globalization

climate change developments, which in turn affect water availability, land use, and conservation of forests and biodiversity. Finally it is important to consider developments in science and technology as part of the future scenarios.

Some of the drivers and trends mentioned affect the demand side of food and agricultural goods, while others influence the supply side, and still others play a role on both, demand and supply. The time frame for the effects may vary as well, with variables like population growth that can be considered as "strategic invariants" within the next couple of decades, while others may change faster (for instance, trade developments, or energy pricing). Also most of the climate scenarios showing clear differences from today play out mainly from 2050 onwards, even though changing weather patterns are experienced now or will be within a shorter time frame. The following Table 15 (adapted from Zahniser, 2012) shows some of the drivers and factors, classifying them into economy-wide or agriculture-specific, and short-term and medium-term.

Table 15. Strategic Dimensions

Strategic Dimensions			
	Economy wide		Agriculture specific
	*Globalization		*Consumption patterns (meat, sustainability requirements, values)
Long-term	*Economic growth and income distribution		*Global biofuel production
	*Population growth		*Productivity growth
	*Energy		*Natural resources constraints
	*Climate change		
	*Exchange rates		*Weather
Short-term	*Other macroeconomic factors		*Stock-to-use ratio
	*Price of oil		*Trade policy
Adapted from Zanhizer, 2012			

In what follows some of those factors and future trends will be discussed, highlighting main uncertainties as a basis for outlining some potential scenarios in the subsequent section.

5.1 STRATEGIC DIMENSION 1: GLOBAL GOVERNANCE AND GLOBALIZATION

5.1.1 OVERVIEW

The large period of world integration during the final decades of the XIX century contributed to faster world growth but was interrupted by two world wars and the Great Depression (see for instance

Frieden, 2006 and Diaz-Bonilla and Robinson, 2001). Next Table 16 shows the average growth in GDP per capita for long periods (data comes from Maddison, A 2010).

Table 16. GDP Growth per Capita.

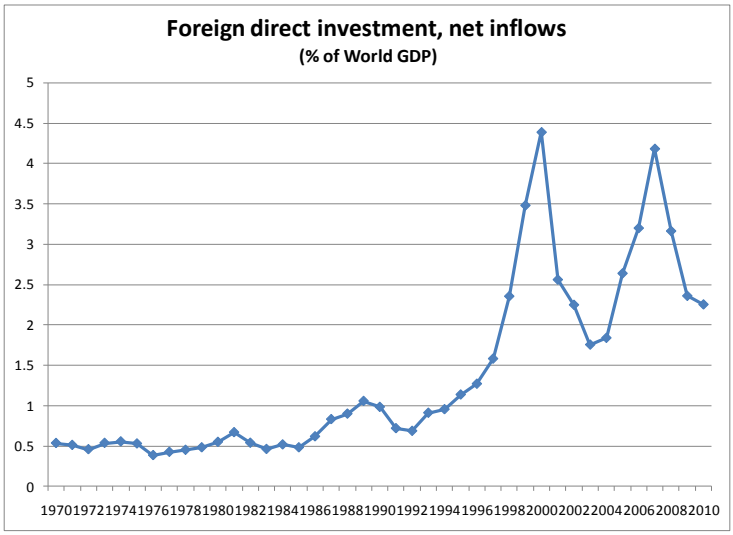
GDP growth per capita (Maddison data)		
Period	Length in years	GDP per capita growth (PPP)
1820-1870	50	0.5
1870-1913	43	1.3
1914-1950	37	0.9
1950-2010	60	2.2

Source: Calculation by authors from Maddison, A. 2010.

The world economy was growing at a modest annual rate of 0.5% per capita during good part of the XIX century. Then a wave of globalization began late in that century, driven by technological changes in industry, agriculture, transport and communications, and by population growth. These developments led to increased trade and financial flows, and migrations. World economic growth per capita more than doubled to 1.3% per year for several decades from 1870 and until about WWI. That war signaled the beginning of a dramatic period that included two global wars and the 1930s economic collapse. The process of economic integration (globalization) collapsed and the world economy slowed down by about a third, to a per capita growth of 0.9% GDP per year.

After World War II and having experienced the horror of global wars and the Great Depression, the countries emerging from those trials defined an architecture for international governance with the aim of avoiding similar tragedies. Although there were opponents, a global system for a more coordinated management of the world economy was established (see the discussion in Diaz-Bonilla and Robinson, 2001). The growth of the world economy accelerated to about 2.2% per capita, in the context of a system that fostered increasing levels of global economic integration, as shown in the next Charts. Figure 20 shows the jump in foreign direct investment (FDI) as percentage of world GDP from about 0.5% in the 1970s to more than 4% in the last two cycles of international capital flows. It must be noted that FDI is just one of the components of international capital flows, and therefore the level of financial integration is larger if other components are also considered (see for instance, Kose, Prasad, Rogoff, and Shang-Jin. 2009).

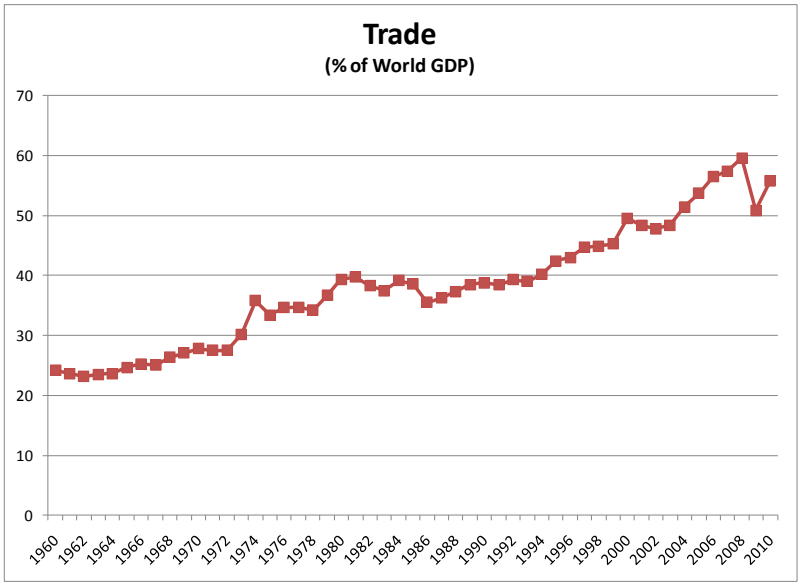
Figure 20. Foreign direct investment, net inflows



Source: World Bank, WDI

Trade (exports plus imports) as percentage of the world GDP has also increased from about 25% in the 1960s to almost 40% in the 1980s and early 1990s (see Figure 21), but then jumped to 60% until the current crisis reduced that percentage. If the incidence of trade is considered only on the tradable part of world GDP, the potential domestic impact of expanded trade is even larger, considering that the service component of the economy (which includes activities such as government, domestic transportation, retail and wholesale, and a variety of locally-delivered services) tends to be more than half of total GDP in most countries.

Figure 21. Trade



Source: World Bank, WDI

The question for the future is whether this process of economic integration, which has been correlated to those higher levels of world growth during the last decades, can continue, or eventually may stop or even be reversed. If that is the case, the high levels of global growth experienced recently may not be sustained (Spence, 2011, and Dadush and Shaw, 2011). Table 16 suggests that a future slowdown that is only half as severe as the one suffered during the period of global disintegration that started after WWI and lasted until early 1950s, would lead to a growth of GDP per capita of about 1.5% for the next decades (the issue of growth is discussed in the next section).

There are important questions marks regarding the future of global integration and global governance. One, of a relatively shorter-term nature, is related to the potential impact of the current financial crisis on the size and composition of the European Union and the Euro, with the multiple and negative ramifications that a breakdown may have on the world economy.

A second and more general issue is the evolution of global economic imbalances and the potential for currency and trade conflicts.[45] A key global policy issue is what international arrangements or institutions can coordinate a cooperative solution to the current economic problems and potentially prevent the kinds of trade and financial imbalances that caused the current crisis. Discussions within the International Monetary Fund (IMF) have focused on the possibility of strengthening economic policy

[45] The Minister of Finance from Brazil has recently referred to "currency wars," a term that has been popularized by the economic press.

surveillance in a way that encourages cooperation. Yet critics argue that the IMF does not have the instruments or the governance system necessary to help design and implement those coordinated policies. More recently the Group of Twenty (G-20), which originally included the participation of Finance Ministers and Central Bank Governors only and has evolved since the crisis into a policy-making body involving Presidents and Heads of States, has been trying to articulate a global collective response to the current crisis and its aftermath. The measures discussed in the enhanced G-20 have included, among other things, fiscal and monetary policies to restart the economies of the industrialized countries currently in recession, reform and better regulation of the banking and financial systems, and increased financing for world trade and for developing countries through strengthened international financial institutions. Lately, the G-20 has also focused on other global issues such as food-price volatility, trade problems, and energy subsidies.

Although there have been discussions about how to redress the current global imbalances, which are linked in part to the U.S. dollar as the main global currency for trade and investment and to the U.S. consumer as "the buyer of last resort," the disequilibrium in current accounts is still high (although smaller than at the peak in 2006-2008) (see for instance, Obstfeld, 2012 and World Economic Outlook, IMF October 2012)[46]. A more profound restructuring of global financial and macroeconomic institutions may be needed, including the issue of a truly universal currency based on, but likely going beyond, the Special Drawings Rights (SDRs) issued by the IMF. A proper resolution of these issues, which will likely occupy politicians and economists in the next decades, is crucial for growth and poverty alleviation going forward.

The third main global issue is related to the evolution of the energy matrix and climate-change negotiations. These negotiations pose major longer-term challenges linked to the interaction of energy, agriculture, the resource base, climate change, and the environment. Even without accelerated growth, potential imbalances loom in world energy markets in the coming years (see section on energy below), and the implications of energy consumption for climate change may carry significant consequences for many developing countries and the world in the medium- to long- term. The complex issues linking energy use, economic development, poverty alleviation, and climate change are also affected by a market coordination failure of global proportions, which—like the shorter-term macroeconomic imbalances—lacks a widely accepted and truly operational international mechanism for resolution.

[46] As an example, according to the latest WEO (IMF, October, 2012), the US deficit in current account that peaked at 6% of the GDP in 2006 would still be around 3.1% in 2012 (and it is not projected to decline further). On the other hand, the current account surpluses in what the IMF calls the Newly Industrialized Asian Economies, which have been over 7% of the GDP in the second part of the 2000s, have declined only to around 5.6% in 2012, with very small further decreases projected for 2013-2017.

The welfare of the whole world, and the fate of the poor, will depend on how those three issues (the European crisis in the shorter-term, global macroeconomic imbalances in the medium term, and the market and institutional failures associated with energy and climate issues in the longer term) are solved. Building a world economy that is macro-economically stable, based on sustainable energy, and capable of ensuring the benefits of progress for everyone requires that humankind properly address those crucial issues of global governance. The architecture that was created by the industrialized countries after WWII is challenged by the emergence of new power centers among developing countries: witness the replacement of the G-7 by the G-20. At the same time, the difficulties of this last group to operate adequately, after the initial coordinated response in 2008-2009, indicate that while the old system of global governance and coordination may not be working properly, there has not yet emerged a functioning new system to replace it.

5.1.2 POTENTIAL DEVELOPMENTS

It is possible to envision at least three alternatives for the evolution of the current global system. One would be a business-as-usual scenario in which the global coordination and governance systems for the main global problems (i.e. the European crisis, macro imbalances, and climate change and energy issues) continue to muddle through. There would not be further global integration, or it will increase at a far slower pace than in the last decades, but there will not be a breakdown of current trade, financial, and macroeconomic linkages. In some of the economic issues, the G-20 and other international organizations will continue to move from one partial solution to another, with recurrent threats of deeper crises, neither quite solving the problems but nor leading to a breakdown of the current global economic system. In the case of climate change, negotiations may continue without reaching consensus on what to do, while independent energy and technology developments and a lower global rate of economic growth, may help reduce in part the path of emissions but not necessarily placing the world on a sustainable level.

In a second scenario, the crisis in Europe leads to a weakening or breakdown of the monetary union in that region, global economic imbalances are not solved, leading to currency and trade "wars," affecting other regional economic pacts (such as MERCOSUR), while there is no positive evolution in climate-change negotiations. The world economy will not grow very much in this scenario; although this lower growth will help slow down the growth of emissions.

A third and optimistic scenario, may consider enhanced coordination to manage global trade, financial, and macroeconomic imbalances, including a proper resolution of the European Union crisis through the consolidation of a United States of Europe, and a world that achieves consensus on energy and climate change policies, including the financing and development of new clean energy technologies. Global growth in this scenario, although faster than the other two, may not go back to the levels of the last

years, at least in this decade, because of the protracted impact of financial crisis of the type suffering the world now (see Reinhart and Rogoff, 2009). The next section discusses economic growth in greater detail.

5.2 STRATEGIC DIMENSION 2: GROWTH

5.2.1 OVERALL VIEW

Estimations of the rates of future GDP growth have large margins of uncertainty, which, obviously, are compounded the farther into the future the projections are intended to go. Several of the current projections utilized in quantitative analysis (such as those discussed below) suggest world growth rates of GDP per capita clearly above the averages for the last 30 or 50 years. Those projections are based on variations of growth convergence models, which assume that currently poorer economies have the opportunity to catch up with richer countries provided they follow adequate policies and that other supporting factors (such as the continuation of global economic integration) remain operational (see for instance Quah, 1996; Islam, 2003 on convergence; and Spence, 2011 on the importance of the continuation of global economic integration). The richer countries are also assumed to continue growing at some substantial steady-state rate, and poorer countries converge towards the more developed countries under some definition of convergence.[47]

There have been criticisms to the empirical reality of convergence at least based on data until the end of the 1990s (see for instance, Pritchett, 1997). However, during the last years, particularly 2003-2007, the world experienced a period of high growth in which developing countries started to close the income gap with industrialized countries. This buoyant period ended with the global financial crisis of 2008-2009. But after the worst part appeared to be over, developing countries continued to converge towards richer countries, in part because industrialized countries have been growing very slowly or not at all. In this current scenario, what it is important to ascertain is not only whether there will be convergence, but what is the future steady state growth of industrialized countries towards which developing countries are supposed to be converging.

To consider the future evolution of the world economy it is useful to analyze growth trends over the last half a century or so, and compare that performance with the projections for the next five decades. The following Table 17 shows growth rates of GDP per capita for the world as a whole from USDA (2012), the three scenarios used in IFPRI's projections (Nelson et al, 2010), the estimates of the Shared

[47] Islam (2003) identifies seven different definitions of convergence, including convergence within an economy vs. convergence across economies; convergence in terms of growth rate vs. convergence in terms of income level; unconditional (absolute) convergence vs. conditional convergence; global convergence vs. local or club-convergence; and others. Therefore, it is important to clarify in the models utilized what type of convergence is postulated. Here we are referring mostly to convergence in growth rates across economies, although in some cases convergence in incomes may be also discussed.

Socioeconomic Pathways (SSP) for the IPCC 5th Assessment (which seem to be the current benchmark values for many simulations)[48], and the projections of the International Energy Agency (which uses that benchmark growth to project energy demand, the price of energy, and GHG emissions). The Table also includes historical values, measured at market exchange rates and PPP exchange rates.[49] There is a debate on whether for the projections should be made using market exchange rates (which reflect the values at which transactions take place in international markets) or at PPP values (because these estimates reflect the "true" valuation of national incomes, separate from transitory changes in exchange rates).

Table 17. Growth Rates per capita

Projections	2010-2020	2010-2030	2010-2050
USDA 2021 a/	2.3	Na	na
SSP 1	3.5	3.5	2.8
SSP 2	3.2	3.1	2.4
SSP 3	2.7	2.2	1.5
SSP 4	3.3	3.0	2.2
SSP 5	3.6	3.7	3.1
IFPRI baseline	2.1	2.2	2.5
IFPRI optimistic	2.9	3.0	3.2
IFPRI pessimistic	1.2	1.1	0.9
IEA reference a/	3.2	2.7	na
Historical	Average 1960-2011	Average 1974-1992	Average 1992-2011
PPP based World Bank	Na	Na	2.0
PPP based Maddison a/	2.1	1.3	2.2
ER Market based	1.9	1.3	1.4

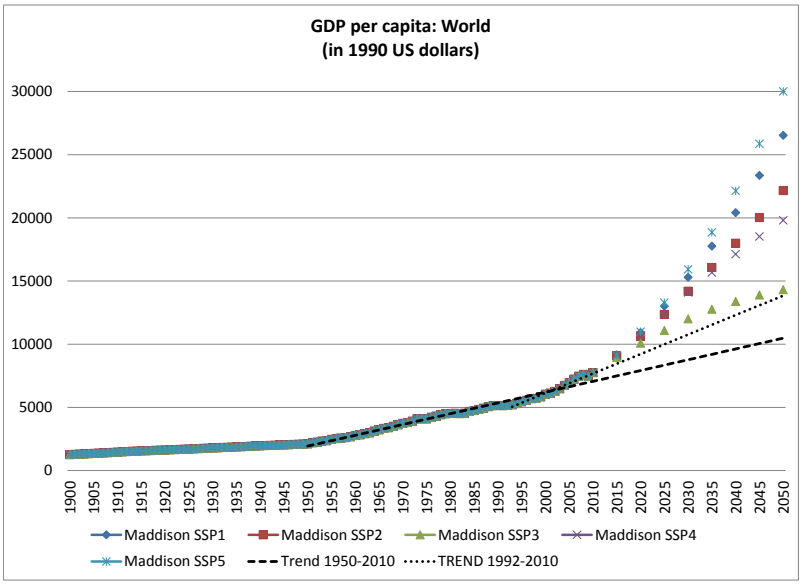
a/ For the USDA the periods are 2011-2012 and 2011-2021; for IEA the periods are 2009-2020 and 2009-2035; for PPP based Maddison data the period ends in 2010.

[48] Those numbers come from the Version 0.9.3 of the SSP Database https://secure.iiasa.ac.at/web-apps/ene/SSPDB. It was accessed on August 2012. A previous version of the database had lower growth rates, although still above the historical numbers. The SSP scenarios come from considering two dimensions of approaching climate change: challenges to adaptation and challenges to mitigation. SSP1 is the more optimistic in terms of both, adaptation and mitigation, while SSP3 is the less optimistic (reflected in lower growth rates). SSP5 is a high grow scenario where the problem is mitigation not adaptation and SSP4 has more problems with adaptation but not mitigation.

[49] Aggregate world growth measured in market exchange rates is usually lower than when calculated in PPP terms. Individual growth rates for each country do not necessarily change (if they were calculated, as they should, in constant local currency units). The difference in the aggregate is the result of the fact that measures of the world economy in PPP show higher shares for developing countries compared to the United States (which is the reference point for the PPP calculations) and other industrialized countries, and because developing countries have been growing faster lately. Therefore, the aggregate in PPP terms shows faster growth than if the size of the economies is evaluated at market rates. For instance, in 2011 East Asia was about 10.5% of the world economy measured in market exchange rates, and about 18% in PPP terms. If the region was growing at 8% in that year, at market exchange rates it would have contributed about 0.84 percent points to the aggregate growth rate (0.105 times 8%), but about 1.44 percent points in PPP terms (0.18 times 8%).

Except scenario SSP3 and IFPRI's pessimistic projection, which are below the 1961-2011 averages, all the other growth rates are above historical values for the last 30 and 50 years. The same can be seen in the next Figure 22 that shows different linear trends for the period 1950-2010 and the last period of growth since the early 1990s to 2011, compared to the five SSPs projections. In this case, all five SSP scenarios are above the linear trend of growth, both considering the whole period 1950-2010, or the late acceleration since the 1990s.

Figure 22. GDP per Capita: World (in 1990 US dollars)



Source: Calculations by authors utilizing Maddison data and the Version 0.9.3 of the SSP Database

To better assess future scenarios for world growth it may be useful to consider what happened during the last half a century or so (once the world emerged from WWII). Since then, the world has gone through three different periods of income per capita growth. The Table 18 uses again Maddison data to show GDP per capita growth in those periods.

Table 18. GDP growth per capita (Maddison data)

GDP growth per capita (Maddison data)			
Period	Length in years	GDP per capita growth (PPP)	
1950-2010	60	2.2	2.2
1950-1974	25	2.8	2.8
1974-1992	17	1.3	1.3

1992-2010	18	2.2	2.2

Source: Calculation by authors based on Maddison, 2010.

The first period goes from 1950 to the mid-1970s; it was a golden period of growth (the world economy grew in per capita terms at about 2.8%), with the world rebounding from the destruction of WWII, while the Bretton Woods agreement and the creation of GATT supported the expansion of trade and the increasing financial integration of the world. This period ended with the inflationary shocks of mid-1970s. The second period goes from the mid-1970s to early 1990s: it was a period of far slower growth (1.3%, less than half the previous period) linked to restrictive monetary policies to control inflation, the restructuring of the world economy caused by higher oil prices, and the debt crisis in developing countries.

The third period, starting in early 1990s and until now (2.2% GDP per capita growth), has been a period of expanded globalization, more expansionary monetary policy (as discussed below), the advance of the European project, and economic restructuring in economies that inserted more market mechanisms into previously centrally-planned and statist economies, such as China and the former USSR. The reduction in State intervention after 1980s and 1990s has also happened in other countries in Asia (for example India) and LAC. This last period ended with the current global economic and financial crisis that is still dragging on, particularly in industrialized countries.

So far the discussion has centered on global growth as an important driver of the world demand for food and agricultural products. But domestic growth is also crucial for domestic demand, which continues to absorb a significant percentage of food and agricultural goods domestically produced. Therefore, it is necessary to look here at LAC growth, both historical and projected. Table 19 (also from Maddison, 2010) shows growth rates for eight LAC countries whose data goes back to 1900.[50] Those countries represent almost 90% of total LAC GDP.

Table 19. LAC: GDP growth per capita (Annual average %)

GDP growth per capita (Annual average %)	
LAC 8 countries	%
1900-1913	1.8
1914-1950	1.5
1950-2010	1.8
1950-1974	2.6

[50] The countries are Argentina, Brazil, Chile, Colombia, Mexico, Peru, Uruguay, and Venezuela.

1974-1992	0.8
1992-2010	1.9
Source: Maddison, 2010.	

Because the first period in Table 19 covers different years than the global economic performance shown in Table 16, growth rates for LAC are not comparable with the performance at the world level. But the other periods include similar annual data. Comparing Tables 16 and 19, it can be seen that while LAC did clearly better than the world as a whole during the period 1914-1950 (0.6 percentage points above the global percentage), the reverse happened during 1950-2010 when the region was 0.4 percentage points below. Dividing the last period into the three sub-periods as it was done before in Table 18 (1950-1974, 1974-1992, and 1992-2010), it is clear that the worse performance of the region was during the middle period (0.5 percentage points below the world average), when many LAC countries were affected by the debt crisis of the 1980s (see Tables 18 and 19). From the historical analysis of agriculture, it can be remembered that it was also that period where the agricultural growth was flagging; this underscore the importance of national, and not only global GDP growth, for food and agricultural production. Next Table 20 shows growth projections from the SSPs for the whole LAC region.

Table 20. LAC: Projected Growth Rates (per capita; annual averages %)

LAC: Projected Growth Rates (per capita; annual averages %)			
	2010-2020	2010-2030	2010-2050
SSP1	2.8	2.8	2.6
SSP2	2.6	2.5	2.3
SSP3	2.2	1.8	1.4
SSP4	2.7	2.5	2.1
SSP5	2.7	2.9	2.8
Source: SSP database			

As in the case of global projections, they also tend to be above the historical averages, all of which calls for a deeper analysis of the reasons why convergence models are more optimistic about the future than what historical trends seem to suggest. In what follows, we try to provide a preliminary answer to that question, focusing particularly on the third period (from the early 1990s to 2010), because it is the one that many analysts have in mind when projecting growth rates into the future and because the estimation of growth models tends to be based on data from the last decades. Therefore, it is important to understand the dynamics of the period from the 1990s and until the current crisis in order to project future

paths for the global economy.[51] In that period, several global developments, which started earlier but hit with full force once the world slowdown of the early 2000s was over, began to impart an increasingly expansionary tilt to macroeconomic policies worldwide. Some aspects were related to the real side of the world economy, such as in the case of China, with a series of reforms that started in 1978. First, the "household-responsibility" system allocated previously collective land into private plots and allowed farmers to keep for themselves the production that exceeded a fixed percentage that had to be paid to the State. This policy change generated strong growth in agricultural production, improved rural incomes, and supported the expansion of rural industries and the domestic market. Second, and after that, there were different policy changes (liberalization of foreign investment, creation of export processing zones) that led to the expansion of export industries, which absorbed large internal migrations of labor from rural areas (Brandt and Rawski, 2008).

But economic restructuring and export orientation also took place in other economies, in several cases before than China. Overall, by the late 1990s and early 2000s millions of workers were incorporated into the global economy because of the policy changes in China, the end of the Cold War, and other labor-expanding developments at the global level. All this put downward pressure on salaries and prices of manufactured goods, helping reduce inflationary trends. The substantial supply-side shock can be better appreciated considering the implied shift in labor supply: the IMF (2007), using the simple approach of weighing each country's labor force by its export-to-GDP ratio, estimated that the effective global labor supply quadrupled between 1980 and 2005, with most of the increase taking place after 1990. In these calculations East Asia contributed about half of the increase because of the rise in working age population and increasing trade openness.

This situation, in turn, influenced the monetary side of the global economy, because it allowed central banks in industrialized countries to maintain more expansionary monetary policies than would otherwise have been possible. In the case of the United States, the easing of monetary conditions started with concerns about the impact of the year 2000 on computer networks and was reinforced after the "dot-com" collapse and the terrorist attacks on September 11 of 2001. Until 2004, nominal rates were kept at very low levels not seen since the 1950s, and they were held low much longer than in the 1950s[52]. This excessively expansionary monetary policy eventually led to the economic acceleration that the United States and the world experienced during the 2000s and until the recent crisis.

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[51] The next paragraphs follow and expand Diaz-Bonilla 2008 and 2009.

[52] The effective federal funds rate was about 1.4 percent (nominal) for the period from December 2001 to December 2004, similar to the nominal rates from mid-1954 to the second half of 1955 and again during part of 1958. In the 2000s, however, rates were kept low for about three years, whereas in 1954–55 they were kept low for only about 15 months and in 1958 for just 10 months.

Monetary policies were also expansionary in developing countries. China maintained a semi-fixed exchange rate regime with the U.S. dollar, which generated current account surpluses and an accumulation of reserves that expanded its own domestic money supply[53] and accelerated growth. The Chinese reserves were invested in dollar-denominated instruments, mostly U.S. public bonds, contributing to the reduction of long-term interest rates. Similar mechanisms operated in several large Asian and Latin American countries: to avoid the disruptions caused by the financial crises of the 1990s, they accumulated reserves in their central banks (which expanded their money supply), and invested those reserves outside their countries, in most cases in dollar-denominated assets, also putting downward pressure on global interest rates. Oil producers (and to a lesser extent other commodity producers), benefiting from the increase in the prices of their products pushed by high world growth, also accumulated reserves, with similar internal and external monetary consequences. Developing and emerging countries became net exporters of capital, which, along with traditional surpluses from Japan, went mostly to the United States.

These capital flows contributed to keeping longer-term interest rates low, and at the same time the U.S. Federal Reserve maintained a policy of very low short-term rates for too long. Low short- and long-term interest rates, and the decline in perception in risk, led to increases in credit and leverage (i.e. debt as percentage of income or similar metrics) and generated to two bubbles in the 2000s, mainly in the US, in the housing and the stock market (the latter of which was a somewhat milder repeat of the late 1990s stock market bubble). Those credit bubbles sustained consumption in the US (and other industrialized countries), which provided the outlet for the expansion of production in East Asia specially.

The U.S. current account deficit (generated mainly by the trade imbalance) reached a record of more than 6 percent of U.S. GDP in 2006 (somewhat more than 1.5% of the world GDP). The continuous expansion of the U.S. trade deficit and low interest rates supported global growth. This growth, in turn, began to push up nominal and real prices of several commodities, particularly metals and energy, which had hit an all-time low before during the late 1990s and early 2000s. The devaluation of the U.S. dollar that started in the early 2000s also added upward pressure to the prices of commodities, which usually move in the opposite direction of the value of the US dollar (see Mundell, R. (2002) and also the discussion in Diaz-Bonilla and Robinson (2010)).

Concerns about inflation meant that the accommodative U.S. monetary policy began to be reversed by mid-2004, putting in motion the events that led to the housing and related credit crises of

[53] The monetary expansion results from the fact that a Central Bank buys dollars from exporters, who receive domestic currency. In the absence of other compensatory action by the Central Bank (such as buying domestic currency with bonds), money supply expands.

2007 in several industrialized countries: the housing market peaked in early 2006 and then started to decline sharply, while the stock market peaked in late 2007 and then turned down.

Clear signs of financial distress in mid-2007 led the U.S. Federal Reserve to adopt a strong change in monetary policy toward a more expansionary stance. The large increases in commodity prices in the second half of 2007 and early 2008 appear to have been influenced in part by this monetary easing. The shift in monetary policy sparked fears of inflation and a decline in the U.S. dollar, prompting investors to turn to commodities as hedges against price increases, in a context in which alternative investments in stocks and other assets did not show good returns. Biofuel mandates and changes in the trade policies of several key countries also contributed to the run-up in prices. Still most real prices of agricultural goods, as mentioned, stayed below their 1970s levels (Díaz-Bonilla, 2010).

By mid-2008 the initially localized financial stress was evolving into a full-blown financial crisis. The unraveling of both bubbles and the tangled and opaque network of financial instruments created around them placed the banking system under stress, generating a run on investment banks and the shadow banking system. A credit crunch ensued, and in 2009 the world suffered the worst recession of the whole period covered by modern statistics (from 1960 to now): GDP per capita declined -3.3% (in market exchange rates) or -2% (in PPP terms) (the worst previous global recession had been in 1982, and world GDP growth did not even turn negative in the aggregate for that year).

A global coordinated response of expansionary monetary and fiscal policies was engineered through the G-20. Also, because the continuous deterioration of the financial system in many industrialized countries, which originally was treated as one of liquidity to be handled with traditional monetary instruments, the approach changed towards the creation of numerous non-traditional instruments to provide liquidity. Faced with insolvency and the possibility of a systemic collapse in the financial sector of the industrialized countries, governments resorted to a variety of guarantees, direct capital injections, public takeovers, and orderly bankruptcy arrangements.

5.2.2 POTENTIAL DEVELOPMENTS

Going forward, policy options remain more limited, given the expansion of the balance sheet of the Central Banks, and the increases in the ratios of public debt to GDP in many industrialized economies, generating doubts in the markets about the fiscal sustainability of major countries, particularly in Europe. These developments are also putting pressure on the continuity of the Euro zone in its present form. Any disorderly management of the current fiscal, monetary and financial situation in Europe and the US may lead to a double-dip world recession, but now governments will not have the fiscal and monetary instruments to implement an anti-recessionary response comparable to 2009-2010.

Even if this downturn is properly managed, industrialized economies will face a relatively protracted period of low growth, at least during the first half of the current decade. There are several reasons for this scenario. First, governments, once growth is re-established, will have to ensure fiscal sustainability after the increases in public expenditures and debt undertaken to support the financial sector and the economy. Also, they will have to ease out of the expansionary monetary policies followed so far. Second, consumers, especially in the United States, but also in other industrialized countries, who increased their debt ratios during the 1990s and 2000s, will have to save and reduce those ratios to more manageable levels. Third, the financial sector emerging from this crisis will be more regulated and will have less leverage. All in all, expenditure adjustments in the public and household sectors in the United States, along with less abundant credit, will lead to lower growth, and, in the case of the U.S., lower trade deficits. The world will thus not have the consumption engine that propelled growth during the past two decades, and it is not clear what can replace it.[54]

Therefore, looking forward there are two main unknowns. The first one, more important in the next five years or so, is the resolution of the current global financial crisis, affecting how much longer the current period of low world growth may continue. It has been shown that financial crises with deleveraging take longer to end (Reinhart and Rogoff, 2009), which, for a given assumed growth rate once the crisis is over, may push the subsequent trend permanently below an alternative one if the crisis had finished earlier. The second issue is, when the crisis is over, what would be the new growth mechanisms that could lead to an acceleration of growth, considering that it is assumed in many projections that economic performance will be at or above historical levels.

The reasons for the acceleration of growth in the last decades have been already discussed: a restructuring of previous centrally-planned and *dirigiste* economies added significantly to global labor availability (a supply-side shock), that began to produce for world markets, particularly the United States, in the context of expansionary monetary policies, that accelerated global demand and made the US the "consumer of last resort" (demand-side accommodation). The imbalances generated by that arrangement are at the center of the current crisis and therefore the growth convergence models estimated during the last decades (which had that arrangement in the background) may overestimate growth going forward. What is needed is a new narrative for the supply-side restructuring and the demand-side expansion that is

[54] Some analysts consider the possibility of an inflationary scenario, as it happened in the second half of the 1970s. The industrialized countries countered the 1974 oil shock with expansionary macroeconomic policies that led to further inflationary pressures in the late 1970s and a complete policy reversal in the 1980s, forcing a deep recession. The fact that prices of some commodities (such as gold) are high reflects the expectations of a scenario in which inflation would move sharply higher in three to four years, forcing a drastic monetary contraction then.

supposed to sustain world growth in the future.[55] One such narrative is the rebalancing of growth internally in China towards consumption and away from investment and exports. However, the size of the variables involved may not impart the same level of impetus to the global economy: after all, during the 2000s, China's GDP, consumption, and imports, in current US dollars have been about 28%, 14.5% and 36.5%, respectively of the equivalent values for the US economy.[56] It has already been pointed out that industrialized economies face a protracted period of lower growth. Therefore, even without the slowing down (or, even worse, reversal) of global integration, the factors mentioned above may keep global growth rates below the ones suggested by convergence models.

5.3 STRATEGIC DIMENSION 3: POPULATION, URBANIZATION, AND CONSUMPTION

5.3.1 POPULATION STRUCTURE AND ECONOMIC GROWTH

The period between 1950 and 2010 was characterized by an important increase in population: the number of people in the planet in 2010 was 2.7 times larger than 1950: almost 6900 million against about 2500 million, or an increase of about 4400 million people. However, that increase in levels took place at declining rates of growth and these will drop further in the next decades, particularly in developed countries. Still, the medium term projections of the United Nations calculate that the world may reach 8300 million in 2030, and 9300 in 2050. The increase will happen basically in developing countries (representing 95% of the additional 2400 million people in 2050), although with different speeds in the various developing regions. The largest increases in population are projected to take place in Africa, which will surpass China in the middle of the 2020s and also overtake India sometime at the beginning of the 2030s.India, in turn, is also estimated to exceed China's population earlier in the 2020s (see Figure 23).

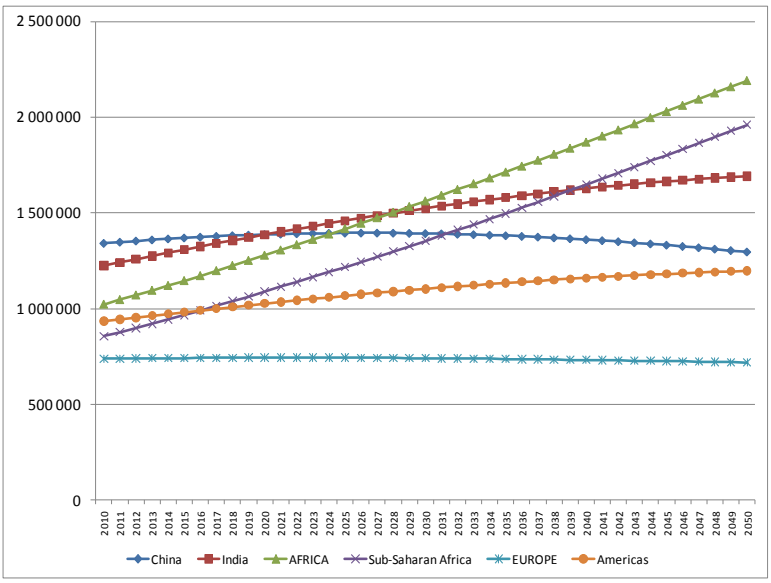
In 2050 the total population in Latin America is estimated at nearly 700 million people with an almost equal participation between men and women (Samaniego, 2012). In Figure 23, all the Americas (i.e. including USA and Canada) have been aggregated to highlight the fact that by 2050, the whole

[55] McMillan and Rodrik (2011) have shown that growth in developing countries is more related to structural change than to the mere accumulation of factors without that structural change. Convergence models focus on the latter and are estimated on growth data that may be reflecting the structural transformation but without variables in the model to pick up this effect.

[56] As discussed before, some data is presented in PPP dollars, which gives China a larger comparative size; while this data may help to perform welfare comparisons, all international trade and financial operations are, obviously, transacted in market (not PPP) dollars. Therefore, here current dollars are utilized to present the average data for the 2000s; if only the year 2010 is utilized, after the US crisis and the expansionary program followed in China after 2008/2009, then still China's GDP is less than half the size of the US economy; China's consumption is about a fifth of USA's; and China's imports are about 57% of USA's.

continent may reach a total population close to the one of China at that time, suggesting important consequences for regional integration within the Americas as a whole.

Figure 23. Population Development



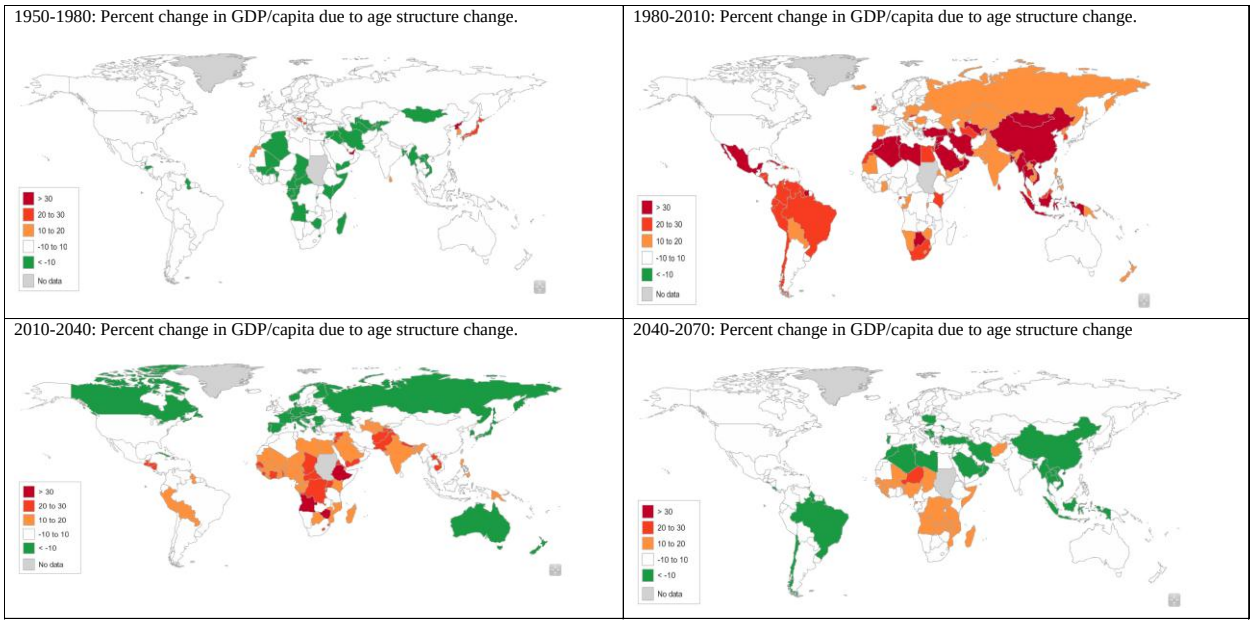
Source: UN Population Database.

There will also be substantial changes in the structure of the population, as a result of dramatic reductions in birth and death rates, particularly in developing countries. The age's composition of a country or region evolves according to the rhythm of age cohorts moving from an age bracket to the next, which, in the context of declining overall rates of population growth, implies the following sequence: first, there is a rise in the young population (0 to 19 years of age), which would eventually decline in percentage when that cohort moves to the next bracket; the rise and eventual decline will happen in the next brackets of young adults (20 to 39 years age); then in the middle-aged adult population (40 to 59 years); and finally there will be a growing population of elderly people (over 60 years of age).

The adjustments in the age structure of the population influence GDP growth: countries or regions whose middle age segments (between 20 and 50 years) are expanding would (other things being equal) benefit from the positive impact on growth of that "demographic dividend" (see Bloom, Canning, and Sevilla (2001)). During 1980-2010, between 20% and 30% of the accumulated growth in most South American countries (except some with older demographic structures, such as Argentina) may be attributed to the demographic dividend (i.e. the fact the middle segments of the population in the region were growing faster) (Samaniego, 2012). Countries like China have enjoyed that dividend in the last decades, but this is changing and now the positive impact of the age structure will act in reverse with the

aging of the population. India, on the other hand, will enjoy (potentially) a demographic dividend in the next decades (Wolf et al, 2011). Important segments of the world economy will enter into what has been called the phase of "aged economies," defined as the situation in which a country devotes to the elderly population more resources than to children (Samaniego, 2012). The "aged economies" will dominate the world demography in the next decades, with important implications for growth, consumption patterns (see below), and other demographic dimensions (see Figure 24).

Figure 24. Percent changes in GDP per capita due to age structure change.



Source: Samaniego, 2012.

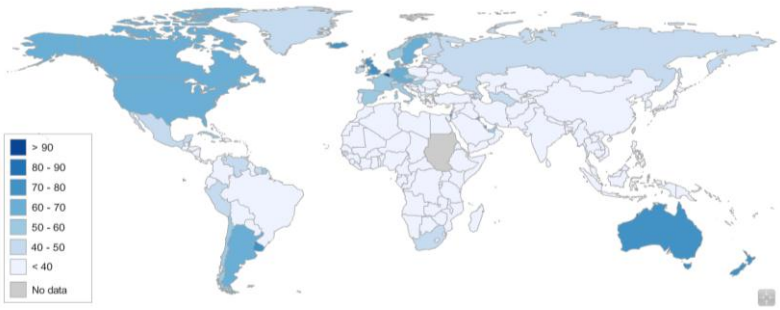
5.3.2 URBANIZATION[57]

Urbanization is a fundamental dimension of the demographic analysis. Currently, cities occupy around 3% of the earth but they accommodate almost half the world's population and account for 2/3 of the total energy use and emissions of GHG's (Samaniego, 2012). The trend towards increased urbanization is projected to continue although with differences between countries and regions. The next Charts show the evolution of this process since 1950 and the expected trend towards 2100.

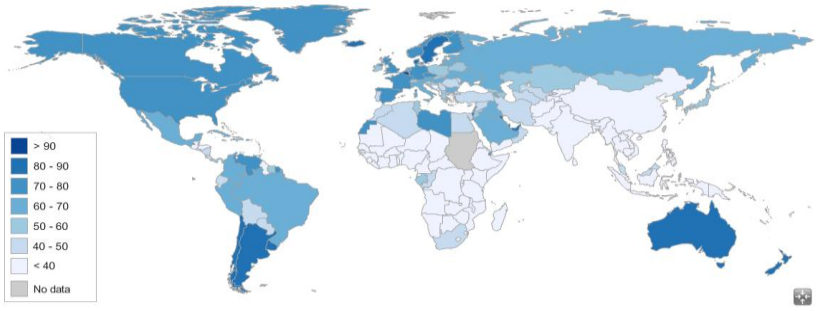
[57] This section comes mostly from Samaniego 2012 (the presentation at the May 2012 workshop) and the sources indicated there.

Figure 25. Percent of national population in urban areas (a).

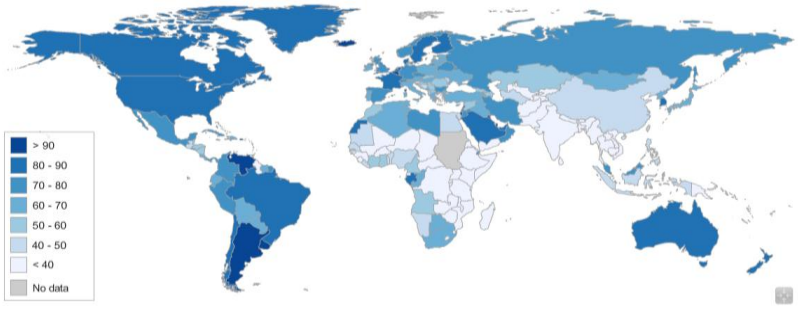
1950: Percent of national population in urban areas.



1980: Percent of national population in urban areas.



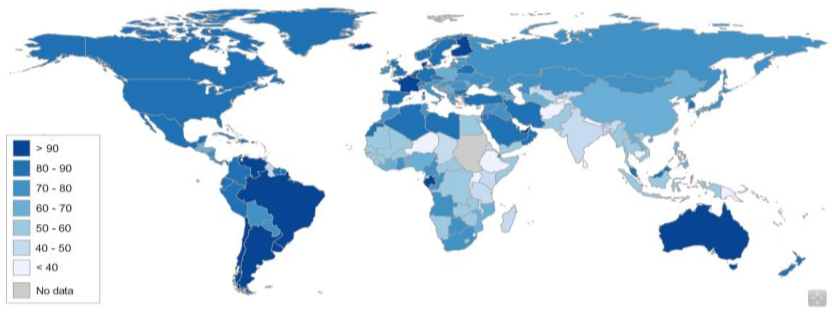
2010: Percent of national population in urban areas.



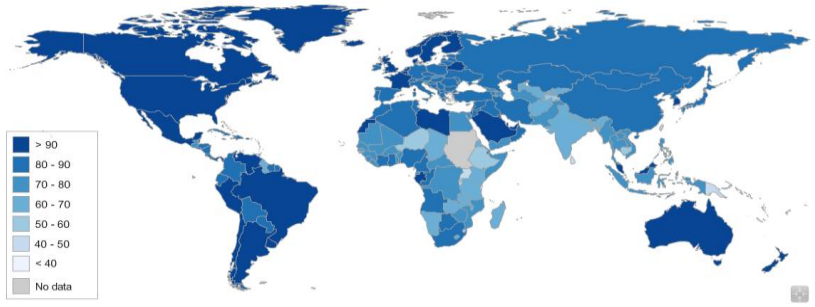
Source: CELADE, 2010.

Figure 25. Percent of national population in urban areas (b).

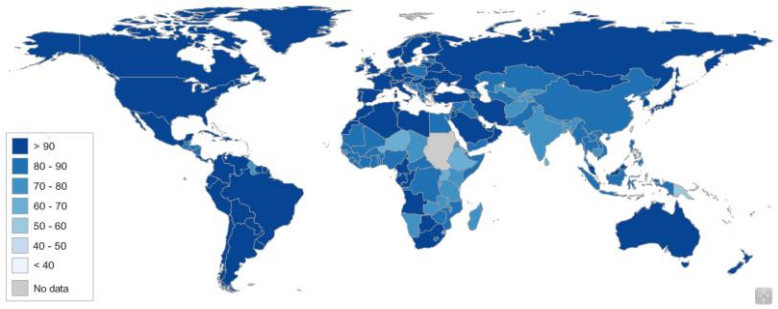
2040: Percent of national population in urban areas.



2070: Percent of national population in urban areas.



2100: Percent of national population in urban areas.



Source: Samaniego, 2012

In past decades, the trend towards increased urbanization was more accentuated in several countries of LAC and the Middle East. Notwithstanding the current high percentages of urbanization in LAC, those rates will further increase in the following decades (to about 85% by 2030 from levels close to 80% now), particularly in countries such as Argentina, Brazil, Mexico, and Chile, followed by other countries such as Colombia and Ecuador (while in Central America and countries such as Bolivia and Paraguay the process will be slower) (Samaniego, 2012).

This urban sprawl may also increase the proportion of poverty belts and gaps in the living conditions and basic needs such as access to drinking water, housing and sanitation services. In LAC approximately 23% of the urban residents are in this situation. In Brazil, almost 45 million people live in slums (Samaniego, 2012). This growth of poverty in the perimeter of the urban areas would continue to expand with increases in population, and poverty will be basically urban in LAC. With those trends, concerns about food security will continue to have a larger urban component.

5.3.3 CONSUMPTION PATTERNS

Usually economic analysis of food demand is linked to incomes, prices, and urbanization trends. But other issues such as marketing policies and the expansion of supermarkets, health concerns, social and ethical values (e.g. organic and sustainable production, animal welfare, and religious beliefs, such as those related to beef or pork consumption in some countries), influence consumption patterns as well (see UK Foresight Report C8, 2011). Also there is a related tendency in some countries towards policies fostering diets that are healthy and sustainable, although the definitions tend to diverge, especially about sustainability, where the economic, social and environmental aspects may point in different directions (UK Foresight Report C8, 2011). Some countries have issued guidelines that may eventually change the patterns of food consumption, particularly regarding red meats, foods that are transported by air, and/or products derived from methods with high fuel inputs and low feed conversion. For instance in Germany, the German Council for Sustainable Development issued food consumption guidelines that not only look at traditional healthy food products, but also provide advice about organic products, seasonal fruits and vegetables grown locally, Fairtrade products, beverages in recyclable packaging units, and suggest the avoidance of foods with high sugar and fat content (see UK Foresight Report C8, 2011).

Concerns about food waste will have an impact on food demand as well (UK Foresight Report C7, 2011). Waste and losses are influenced by global drivers such as urbanization (which requires that food supply chains be extended to feed urban populations), the dietary transition from consumption of less perishable starchy food staples and towards a diet with more perishable products such as fresh fruit and vegetables, dairy, meat and fish, and the expansion of international trade in food products (which further extends the length of the food supply chains) (UK Foresight Report C7, 2011). If waste is assumed

to reach 30% of total food and that by 2050 the usually quoted expansion of 70% of food production would be needed to feed the growing population, then halving that waste by 2050 would reduce the food required by about 25% of today's production (UK Foresight Report C7, 2011).[58] Of course, much of the waste to be avoided would come from private sector decisions (mainly in the food chain beyond the farm and closer to the final consumer) and/or public sector investments unrelated to agricultural R&D as such. But a strong effort to reduce waste may then mitigate the imperative for R&D to increase production in the agricultural and food sector.

It must be emphasized that the sources of waste and the place in the food chain differ significantly between developed and developing countries: in the first case, they occur more at the level of the final user (related in many cases to private sector standards and consumer choices), while in the second case losses happen mostly between harvest and processing (usually because of lack of infrastructure) (see UK Foresight Report C8, 2011).[59]

A generalization of all the consumption trends mentioned above can have a substantial impact on the level and composition of food demand. This is particularly so in the case of meat consumption, where it is difficult to determine whether cultural differences will maintain intakes low, or there will be a stronger convergence to higher levels of consumption, making projections very difficult (UK, Foresight Report C4, 2011). The next Chart (from Zahniser, USDA, 2012) shows the important uncertainties related to meat consumption preferences and choices.

Figure 26. A change in dietary preferences

[58] If production needs to grow from 100 units (today) to 170 units (2050), and there is a 30% loss throughout the period, then losses in 2050 amount of 0.3 times 170= 51 units. Halving those losses means that 25.5 units of food will be available, therefore reducing the need to increase production by about 25% of the base period (25.5/100).

[59] A recent study by the Asian Development Bank and IFPRI (Reardon et al, 2012) on food value chains for rice and potatoes in Bangladesh, China and India, has shown that contrary to common perception waste (at least for those staple crops) does not seem that important. They find that, while it is often asserted that waste may be about 30%–40% of the costs in the food supply chain, there is only about 7% physical wastage in the potato value chains (from harvest on the farm to retail sale in the city), and in the rice chains was only about 1%–2%. This appears to be the result of better infrastructure (cold storage and road infrastructure) and the spread of mobile phones. There are no similar detailed analyses for other products and countries.

A Change in Dietary Preferences Regarding Meat Could Have Far Reaching Implications for Agriculture

Eating Pattern Comparisons: Average Daily Intake of Protein Foods at or Adjusted to a 2,000 Calorie Level

Food	Food Pattern			
	Usual U.S. Intake, Adults	USDA Food Pattern	Lacto-ovo Adaptation	Vegan Adaptation
	Ounce Equivalents			
Meat	2.5	1.8	Zero	Zero
Poultry	1.2	1.5	Zero	Zero
Eggs	0.4	0.4	0.6	Zero
Fish and seafood	0.5	1.2	Zero	Zero
Beans and peas	0.1	0.2	0.2	1.9
Nuts, seeds, and soy products	0.5	0.6	3.5	3.6

Source: Zahniser, 2012.

Msangi S. and M. Rosegrant (2011) estimate that a reduction in half in meat consumption from the projected 2030 levels would cut real prices of beef, pork, lamb, and poultry by about 19-22% by that date. If large developing countries such as China and Brazil also have meat consumption levels at half the values projected for 2030, prices decline would reach about 34-59% of the 2030 real levels that would have prevailed without those consumption adjustments.

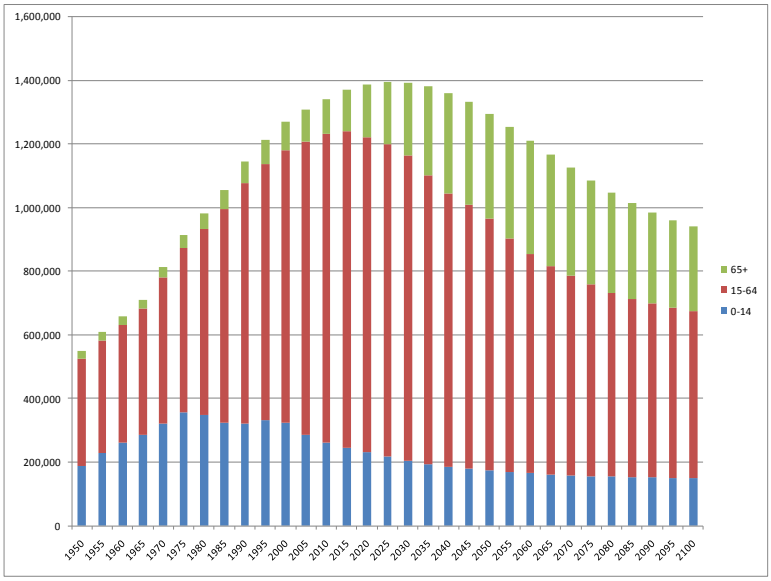
For developing countries, the issue of a declining percentage of income devoted to food (sometimes called the Engel coefficient) with increases in incomes (perhaps in a non-linear way) has also to be considered. Therefore, food-demand projections with fixed coefficients should be avoided (UK Foresight, 2011a).

Another issue relates to the composition of age and gender of the population to project future demands. In most exercises it is generally assumed a relatively stable demographic structure; however, as discussed before, that age structure is changing, particularly in systemically important countries, like China (Zhong, Xiang, and Zhu, 2012). These authors note that China is experiencing fast economic growth, but per capita calorie intake may not be growing as price and income projections would suggest. They attribute that fact to the changing age structure, which leads to declining requirements of calories or energy intake because of the aging of the population. Therefore, projections of food intake should be related not only to prices and incomes but also to the age and gender of the population. The next Chart shows the pattern of population growth and age structure in China to 2100.

The growth of the working age population has probably stopped already, and will begin to decline from 2015 onwards, with the negative implications for growth discussed before (i.e. a negative

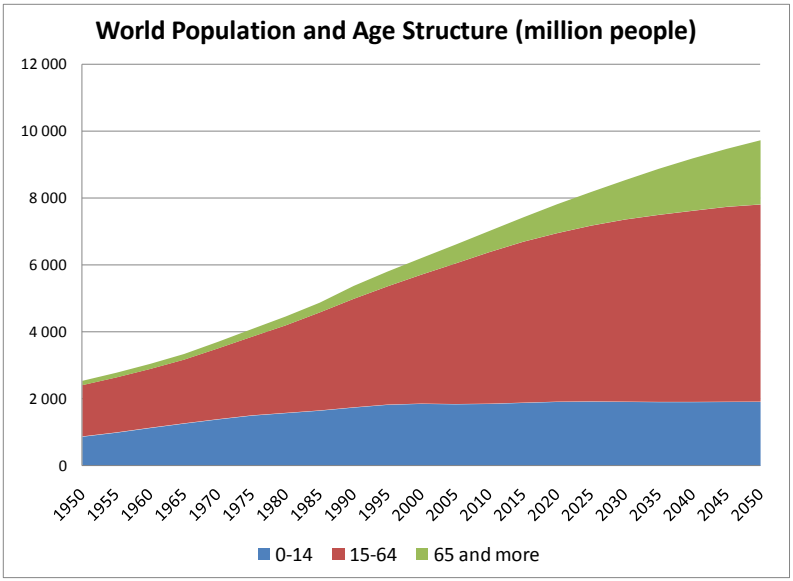
"demographic dividend"). It can also be seen the increase in the age group of 65 years and more. The next Figure 28 shows the same age breakdown for the world as a whole that is also entering a period of expanded population in the bracket of 65 years and older.

Figure 27. Pattern of Population Growth in China



Source: UN Population Database, 2012.

Figure 28: World Population and age structure (million people).



Source: UN Population Database, 2012.

The next Table 21 converts total population to adult-male equivalents (see FAO/WHO/UNU, 2001 and Zhong, Xiang, and Zhu, 2012), which may give a better indication of food demand considering not only prices and incomes but also the age and gender structure of the population. Figure 29 shows the evolution of total (unadjusted) population and adult-male equivalent population. The conversion to adult-male equivalent population shows a more moderate increase from 2010 to 2050: the UN medium-level population projections suggest a world of about 9300 million people by 2050, with an increase of about 2400 million people from the current levels. However, transformed into adult-male equivalent (which would standardize the population from the perspective of food demand), the total is about 5800 million people, with an increase of 1400 million people, or a 1000 million less than if population is not converted into a common equivalent.[60]

Table 21. Total Population converted in Adult-Male Equivalent.

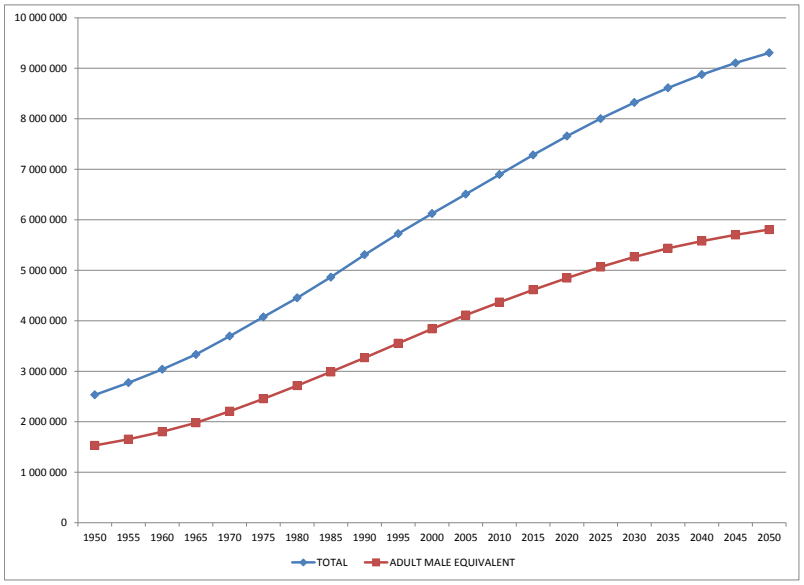
	Total Population	Adult-Male Equivalent
1950	2 532 229	1 531 030
2010	6 895 889	4 367 354
2030	8 321 380	5 265 811
2050	9 306 128	5 806 407

[60] Depending on how the projections are calculated, these differences may be quantitatively more or less substantial. In principle, if all consumption is transformed on a comparable per capita basis, then the difference from using adjusted numbers would amount in 2050 to about 6% less total consumption than using unadjusted numbers. This decline appears not as drastic as what a reduction in 1000 million people would seem to imply because adjusted population, although smaller in numbers, also consumes more per capita.

Increase 2010/1950	4 363 660	2 836 324
Increase 2030/2010	1 425 491	898 457
Increase 2050/2010	2 410 239	1 439 053

Source: Calculations by authors.

Figure 29. Evolution of the total population and the adult-male equivalent population.



Source: UN Population Database and Calculations by authors

5.3.4 POTENTIAL DEVELOPMENTS

Consumption patterns present many uncertainties. In addition to the currently accepted scenarios that project solid increases in food demand, it would also be important to consider adjustments such as those related to aging, the possibility of variable Engle coefficients, meat consumptions levels that may not convergence towards those of developed countries at the speeds assumed, and stronger consumers' movements to reduce waste and request sustainability requirements. Using these alternative assumptions may lead to lower levels of projected food demand. Therefore, it is important to consider the implications for food consumption of all those assumptions.

5.4 STRATEGIC DIMENSION 4: ENERGY

There have always been important direct and indirect links between agriculture and energy. Energy is an input for agricultural production, related to mechanization, irrigation, fertilization, drying, and storing. Agroindustrial production and commercialization also requires energy for processing,

packaging, transportation, storage, and retail activities to place food and agricultural goods in the hands of consumers. Also, different forms of energy are used by consumers to preserve, store, prepare, and cook food, with poor rural households resorting to biomass energy for cooking and heating, with negative implications for their health and the environment. At a more general level, energy costs affect disposable incomes and the demand for other goods and services, including agricultural goods. In particular, sharp increases in the price of oil have been crucial factors in many recessions (Hamilton, 2011) generating declines in aggregate demand and, then, in commodity prices.

In world markets, prices of oil and agricultural commodities have been correlated since at least the 1970s, but this phenomenon seems to have been accentuated more recently because of what has been called the "financialization" of commodities (i.e. commodities becoming investments options, in part as hedges against inflationary developments).[61] Also in recent times, the links between energy and agriculture expanded further because at least two additional factors. One has been biofuel mandates, which appear to have been one of the causes of the recent spike in food prices by expanding the demand of agricultural products as raw materials for biofuels (see for instance, von Braun, 2008; and Headey & Fan, 2010). To have a sense of the direction of causality (i.e. whether developments in energy markets are driving results in agricultural markets) it may suffice to note the differences in size: if all the food energy needed for human beings to function and all the nonfood energy used by the world to operate were calculated in a common measure (joules, for example), the latter amount is about 16 to 18 times higher than the former. Finally, another link between agriculture and energy is related to longer-term climate-change impacts (Nelson et al, 2010) and shorter-term weather variability (Hansen, Satoa and Ruedy, 2012), associated to energy-elated green-house-gas (GHG) emissions. What follows emphasizes the oil market, because of its larger share in energy sources, the multiple uses in transportation, electricity, and manufacturing, and as the reference for the pricing of other sources of energy (see Espinasa, 2012, and International Energy Agency, 2011).

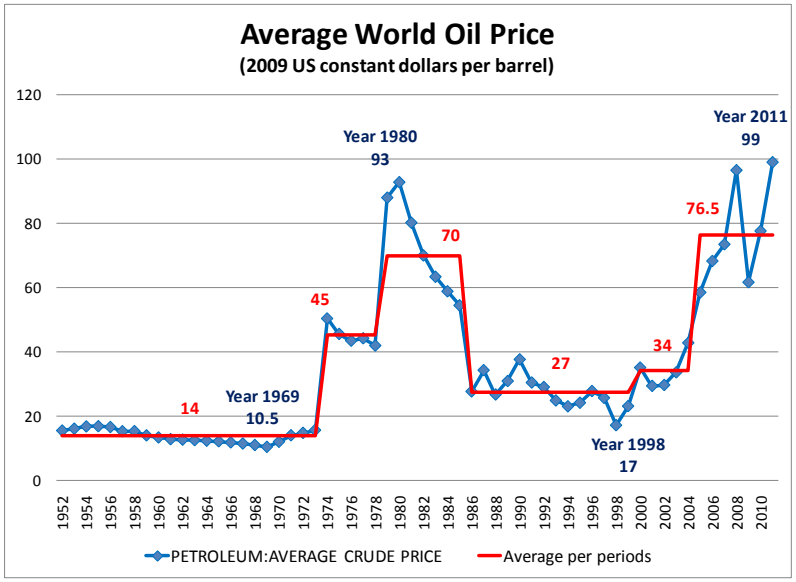
5.4.1 HISTORICAL VIEW

Before going to projections is important to take a retrospective look of the oil market. Figure 30 shows the average world price in constant 2009 US dollars (it is the average oil price from the IMF/IFS data

[61] The importance of this effect is hotly debated; see for instance Juvenal and Petrella, 2012 and Kilian and Murphy, 2012.

base, which includes Dubai, Brent and WTI prices; deflated by the US CPI). The next Chart shows world oil production (from BP database[62]).

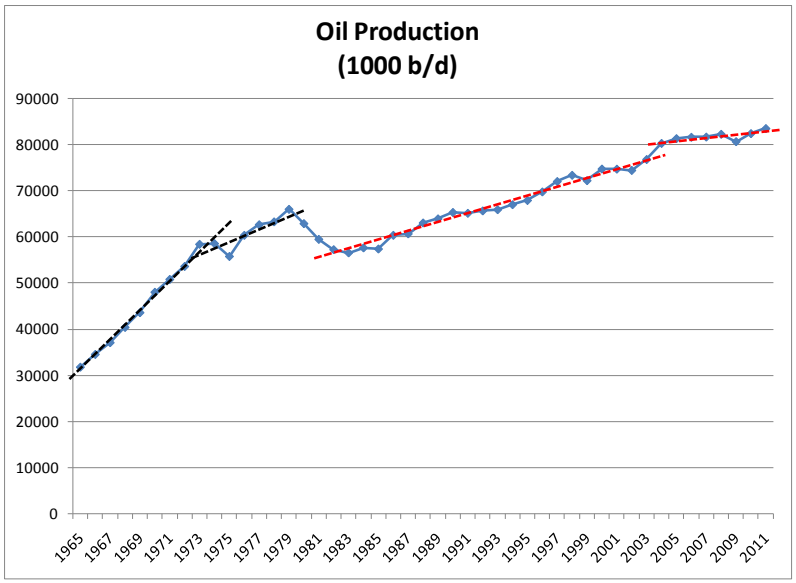
Figure 30. Average World Oil Price



Source: IMF International Commodities Statistics

Figure 31. Oil Production (in 1000 b/d)

[62] The definition of production includes crude oil, shale oil, oil sands and NGLs (the liquid content of natural gas when this is recovered separately), but excludes liquid fuels from other sources such as biomass and coal derivatives. Definitions of what constitutes "oil production" vary in different sources, from very narrow ones which include only conventional crude oil, to more general ones, which consider oil generated from other sources (see for instance the explanation in Sorrell et al, 2010)



Source: BP database

The history of oil prices during the last half century shows that only in two periods during the late 1970s and early 1980s, and now in the 2000s, the real world price (measured in constant 2009 US dollars) stayed for several years at or above 70 dollars/barrel (on average), with annual peaks of 93 dollars/barrel for the year 1980 and about 97-99 dollars/barrel in 2007 and 2011, respectively. Obviously, the evolution of real prices has been affected both by macroeconomic aspects (acting on the demand side) and supply developments. The strong global growth cycle in 1960/1970s and the devaluation of the US dollar after the collapse of the Bretton Woods monetary arrangement were important factors in the commodity price spikes of the mid 1970s, and expansionary macroeconomic policies in the second half of the 1970s contributed to the second price spike. On the supply side, the Yom Kipur war and the OPEC oil embargo (October 1973) and the start of the Iran-Iraq war (in 1980) slowed down world production growth (see the shift in trend in Figure 31), and were also crucial factors for the price increase in those years. Here, only the price of oil is shown, but there were also price spikes for agricultural (and metal) goods during the 1970s, pushed as well by the macroeconomic cycle, trade policies in some countries, and supply-side problems during those years (see a more detailed discussion in Diaz-Bonilla, 2010).

The global recession that started in the US in the late 1970s and early 1980s, the debt crises in developing countries (demand side), and the new technologies that opened the expansion of deep sea oil extraction in the North Sea and weakened OPEC (supply side), were all factors that eventually led to the collapse of energy prices in the mid 1980s. In that context the continuous advance of the Green Revolution was also supported by lower oil prices, which helped to keep fertilizers price and energy costs in general under control. Again, weak demand and supply expansion affected other commodities as well

(Díaz-Bonilla, 2010). Real prices stayed comparatively low (at about 27 US dollars, constant 2009) since the mid-1980s until the late 1990s, with a bottom of 17 US dollars in 1998, when the 1997 Asian crisis and subsequent financial crises in other emerging economies reduced global growth and aggregate demand (Diaz-Bonilla, 2010).

The supply side was also affected by the drop in oil-producing investments due to low prices, the fact that some important areas in OECD countries reached production peaks in the 1990s, increased geopolitical risks in the aftermath of the September 2001 terrorist attacks, and the more recent Iraq war. All these developments led to a deceleration of supply (as shown by the flattened production trend since mid-2000s in Figure 31). On the demand side, the world economy (particularly developing countries) began to accelerate strongly in the 2000s expanding demand (Espinasa, 2012), and the US dollar started to devalue since the early part of the decade, as a result of a very expansionary US monetary policy. All those factors led to the rapid increase in oil prices during the 2000s, which pre-dated the subsequent increases in agricultural prices (Diaz-Bonilla, 2010).[63]

5.4.2 Long Term Energy Outlook

Now the world has just ended a second period of accelerated growth. What are the prospects for oil prices in that context? There are many unknowns going forward. The traditional economic view is that except for short-term supply side shocks (such as geopolitical turmoil in producing countries), higher prices will generate the investments and the technological response to expand supply in the medium- to long-term. In fact, many long term projections for the oil market are based on demand projections, with supply simply filling the gap, based on prices, the marginal cost of new discoveries, and the investments needed for that balance to take place.[64] On the other hand, the geological view is that there may be some "hard supply constraints" that will be difficult to overcome, and at some point oil production would peak and then decline (see the discussion in Benes et al, 2012; they construct a model that tries to estimate econometrically both views).

Table 22 shows price projections from different sources. It must be pointed out that price assumptions are not price forecasts, but are calculated, as mentioned before, to generate sufficient investment in exploration and production so as the supply matches the projected demand over the

[63] In the 1970s the price of food increased before the price of oil, while during the last price spike the reverse happened (Diaz-Bonilla, 2010)

[64] Those estimates operate as follows: a) demand is projected based on income and population growth, urbanization, and other variables; b) then the investments needed to fill the gap between current supply and needed supply are estimated; and c) based on some view of the marginal costs of exploration and extraction, then prices are projected based on the incentives required to generate the investment that would lead to the supply response needed; however, there is not necessarily a feedback loop from those prices to the growth estimated in step (a).

projection period. In that sense it is based more on the economic view, although it includes a geological view in the assumption of increased marginal costs to put new reserves into production.

Table 22. Projections of World Prices

	2020	2035
(2009-2010 US dollars per barrel)		
US AEO 2011 (Reference Case)	108	125
IEA (Current Policies Scenario)	118	140
IEA (New Policies Scenario)	109	120
(current US dollars per barrel)		
IEA (Current Policy Scenario)	148	247
IEA (New Policies Scenario)	136	212
OPEC WOO (Reference Case)	85-95	133
From: US EIA, Annual Energy Outlook 2011; IEA WEO 2011; IEF/IEA/OPEC 2012		

Projections from the US EIA and the IEA in real terms (constant 2009 dollars) show an increase of between 10%-20% for 2020 over the average price of 99 dollars/barrel in 2011, and a 20-40% for 2035. Projections by OPEC (see nominal projections) are far lower.[65] The OPEC assumed price is about half the one in IEA's projections (nominal terms), implying a real price of about 75 dollars/barrel which is about in line with the average real price since the mid- 2000s, but stays clearly below the peak of 2011 (99 dollars/barrel).

A main source of discrepancy in projections is the difference in assumptions about energy and environmental policies during the period considered. For instance, WEO 2011 uses as a central projection what it is called New Policies Scenario, which takes into account government policies related to environmental and energy-security issues that have been already announced, while the OPEC Reference Case (and WEO's Current Policies Scenario) includes in the projections only policies that are already in

[65] Based on IEA's World Energy Outlook (WEO) and OPEC's World Oil Outlook (WOO), both released in November 2011. The IEA WEO reports average IEA crude oil import price as a proxy for international oil price and OPEC uses the OPEC Reference Basket (ORB) crude oil price.

place by the time of the projections.[66] Still, in the simulations with only current policies, the prices projected by IEA are clearly above those of OPEC (see the nominal variables).

Benes et al (2012), based on research at the IMF, follow a different approach from both IEA and OPEC, combining in an econometric model the economic and geological view. The authors project constant (2011) prices of 170 dollars for 2020, far higher than both US EIA and IEA projections. Prices that in real terms are about double or more the average for the two high price episodes in the 1970s-1980s, and now in the 2000s (such as those of IEA, 2011 and Benes et al, 2012) raise important questions marks regarding the sustainability of growth rates for the global economy assumed in those studies. IEA considers that the world economy would grow at 3.6% per year over the period 2009-2035; the IMF methodology has a varying growth rate, but the underlying trend for the global economy is postulated (without much elaboration) to be 4% per year, that may go up or down somewhat depending on oil prices. As discussed in the growth section, those rates of economic growth are clearly above historical ones. Benes et al (2012) acknowledging that their model, although not as pessimistic as the pure geological view, still projects very high real oil prices over the coming decade, recognize that this would de "uncharted territory for the world economy," considering that such real prices have never been sustained for very long periods without triggering a world recession.

Notwithstanding the differences in price projections, other aspects of the projections from the IEA and OPEC coincide.[67] The demographic assumptions are from the United Nations, Department of Economic and Social Affairs, Population Division (UNPD); in all scenarios world populations grow from an estimated 6.9 billion in 2010 to around 8.6 billion in 2035, an average rate of increase of 0.9% per year; most of the growth occurs in developing countries; and the process of urbanization is assumed to continue unabated. Regarding economic growth, it has been already mentioned that IEA WEO assumes that the world global economy grows on average at 3.6% per year over the period 2009-2035; OPEC's WOO-2011 assumes that the global economy will grow at 3.4% per year (2011-2035). As it has been pointed out, adjusting for the 0.9% population growth rate, the implied growth in per capita terms (almost

[66] Some examples of policy commitments and plans to tackle energy insecurity, climate change and local pollution, and other energy-related challenges include a) renewable energy and energy-efficiency targets and support, b) programs relating to nuclear phase-out or additions, c) national pledges to reduce greenhouse-gas emissions, d) initiatives to phase out inefficient fossil-fuel subsides, e) transportation policies (higher efficiency in internal combustion engines, support for hybrids and electric vehicles, use of gas in transportation, regulation of efficiencies in commercial vehicles, support for alternative fuels, such as biofuels, and international marine bunker regulations for more fuel efficiency in this sector). From the enumeration it is clear that the implementation or not of those policies may make a big difference in future energy use.

[67] What follows is based in part on a paper prepared by the International Energy Forum (IEF) in consultation with IEA and OPEC for the IEA-IEF-OPEC Symposium on Energy Outlooks. 23rd-24th January 2012, Riyadh.

2.5-2.7%)[68] is significantly higher than the historical values discussed in the section on economic growth.[69] Both organizations also consider that under all scenarios global primary energy demand continues to grow because of increases in incomes and population. In the scenarios with current policies both IEA and OPEC project that demand for energy in 2035 about be 50% larger than it is now. In the case of IEA's New Policies Scenario the demand for energy increases by 30%, the result of the implementation of a policy package that eliminates subsidies and promotes energy efficiency, among other things.

The IEA and OPEC outlooks differ in the regional cost assumptions and the levels of projected investments that may be needed in producing fields and for additional capacity to meet demand by 2035. They also differ in the importance of production of biofuels, with OPEC projection in the Reference Case being around 2.4 mb/d (on a volume basis) higher than the IEA's Current Policies Scenario.

The IEA study looks at the implications of those projections for GHG global emissions: in the case of the New Policies Scenario, IEA calculates that the level of emissions is consistent with a long-term average temperature increase of more than 3.5°C, and that following current policies temperature may increase by 6°C or more. Therefore, IEA estimates a scenario (the "450 Scenario") based on the international goal of trying to limit long-term increase in the global mean temperature to 2°C above pre-industrial levels, and urges to implement this scenario without further delays, considering that the energy-related capital stock already in place would by itself generate 4/5 of the total CO2 emissions by energy sources allowed until 2035 (IEA, 2011).

In the case of LAC, since 1970, the energy matrix has changed very slowly, with two sectors leading the fuel demand: transport and electricity. There may be some fuel substitution in the energy sector, but it is more difficult in transportation (Espinasa, 2012). With these projections, it will be required a strong policy effort to maintain the world under the 450 Scenario. The development of new technologies is a crucial and unknown factor in achieving more efficient systems, both for production (reducing costs) and demand (improving the consumption fuel efficiency).

A particular technological development is the evolution of unconventional sources of energy, mainly shale gas and tight oil. The IEA (2012) develops a scenario of a "golden age" for gas, based on the application of "golden rules" for the extraction of unconventional gas.[70] These rules consider the need to

[68] The proper calculation is 1.036/1.009 = 1.0267, or 2.67% growth rate for GDP per capita. Subtracting 0.9 from 3.6 is just an approximation.

[69] OPEC also analyzed a lower growth scenario that, obviously, leads to oil prices lower than in the Reference Case.

[70] Unconventional gas resources include shale gas, tight gas, and coal-bed methane. The largest component is shale gas. Almost all shale gas reservoirs (or "plays") produce some liquids, including oil (which are called natural gas liquids, NGL), and tight oil production comes with some associated gas as well. The co-production of oil along with shale gas, helps with the economics of unconventional gas production.

ensure environmental sustainability to the production of unconventional gas. If the expectations about economically usable reservoirs materialize,[71] those environmental rules are applied, and other conditions apply,[72] then IEA (2012) projects an accelerated production of gas, leading to lower prices of gas, and an expansion of gas demand (which increases by more than 50% between 2010 and 2035). As a result, the share of gas in the global energy mix grows from 21% now to 25% in 2035, and overtakes coal, becoming the second-largest primary energy source after oil. Under this scenario the United States becomes the main world gas producer, surpassing Russia. Also China increases significantly its production, as well as Australia, India, Canada, and Indonesia.

As a result of the greater use of gas, GHG emissions are 0.5% lower than in the baseline calculated by IEA. This positive but small effect results from two competing forces: on the one hand, lower natural gas prices lead to the displacement of other sources of energy, particularly coal and oil, that are more carbon-intensive; on the other hand, also because of lower prices, there is a small increase in overall demand for energy and lower-carbon energy sources, such as renewables and nuclear power, get displaced as well. The beneficial impact on lowering GHG emissions may be larger in specific countries like China, where gas is expected to replace part of the coal used for energy production.[73] In the US the expansion of shale gas has already drove domestic natural gas prices lower, disconnecting the value in the US market from the price of other benchmarks such as the traded LNG and the price of Russian gas to Europe (Figure 32). In 2012 US prices went further lower (around US$2-3/btu) closer to levels in the 1990s, supporting the competitiveness of different energy-intensive industries, including the production of fertilizers, and substituting for coal-based electrical plants, which may help to reduce GHG emissions in the US (if, as discussed above, the effect of replacing coal is not countered by the disincentive effect on other cleaner technologies).

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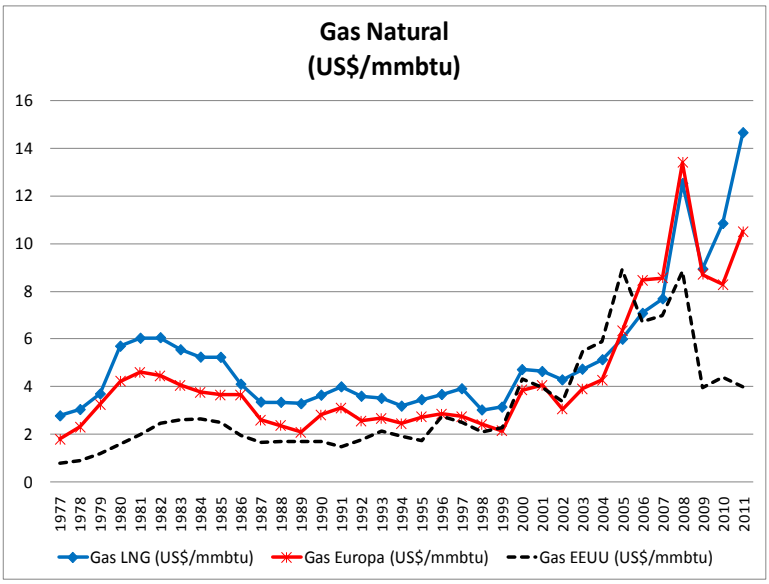
[71] The estimations differ with those published by the US Energy Information Administration in 2011 being higher than those of the United States Geological Survey (USGS) (IEA, 2012).

[72] Other conditions for the expansion of gas include (IEA, 2012): a) access to resources (including adequate geological data, adequate licensing schemes); b) appropriate fiscal and regulatory frameworks to make investments viable; c) availability of expertise and technology, including the required large number of wells, a skilled and experienced workforce and an adequate service sector with the necessary equipment; d) infrastructure for transportation and use of the expanded gas supply; e) existence of markets and pricing schemes that provide the incentives to develop the gas; e) water availability, considering that water is essential for the production of unconventional gas; water-stressed areas and competition with other users may impede the production of unconventional gas.

[73] In any case, the "golden age" scenario implies CO2 emissions that lead to a concentration of GHG of about 650 parts per million, which may lead to temperature increases of more than 3.5°C. Therefore, by itself greater gas use will not place the world on the path of a concentration that does not exceed 450 ppm, and several other things will be required to stay on that path. Conversely, IEA estimates that if the development of unconventional gas is halted because of local environmental concerns, GHG emissions will be even higher, in part because of many countries being then locked into investments in new coal-fired power plants that have long operating lifetimes. This shows a clear trade-off between local and global environmental objectives.

Figure 32. Gas Natural



Source: IMF International Commodity Statistics

If the "golden gas" scenario materializes, and China also embarks (as it has planned) in an accelerated use of unconventional gas, the impacts will be multiple: from less coal-based electrical plants and therefore less GHG from that country, to cheaper fertilizers which may support the competitiveness of food production there. In the "golden gas" scenario (IEA, 2012), LAC also increases its gas production (with an important component of unconventional sources) by almost 80% between 2010 and 2035, and moves from about 6% to somewhat more than 7% of world gas production during the same period. Besides the impacts mentioned for China, in LAC, the increase in gas production would lead to more exports of energy (which will be supported as well by expanded oil production, in part from other unconventional sources such as the deep sea, pre-salt reservoirs, in Brazil). Therefore, considering that exchange rates are usually more market-based in LAC than in other developing regions, the expansion of energy production and exports may have a impact on the appreciation of real exchange rates (a Dutch-disease effect), with a likely negative effect on tradable sectors, such as agriculture. This effect has to be considered against the potentially positive consequence for agricultural growth of cheaper fertilizers and increased economic growth and, therefore, expanded domestic demand in those countries.

5.4.3 POTENTIAL DEVELOPMENTS

In summary, future estimations of this crucial driver are hampered by important differences concerning the future evolution of demand, in part because of uncertainties about a) what energy and environmental policies will be implemented and their impacts; b) economic growth assumptions and

demand growth in China, India, the Middle East and other places; c) differing views about non-OPEC supply evolution; d) diverging expectations of technological change; e) the definition and availability of spare capacity; and f) what are the projected marginal costs of oil supply and the investments needed to equilibrate the markets in the medium- to long-term, among other things (IEA-IEF-OPEC, 2012). However, assuming the strong global growth used in these projections materializes, the pressure on demand side for energy, food and commodities will persist. Although the world may have energy resources to supply the growing demand, bottlenecks would remain because of the usual delays in the development of infrastructure, transport and processing of the primary commodities. In the coming decades, global economic growth may be quite cyclical, affected by recurrent price spikes due to restrictions in the supply of oil (Espinasa, 2012; see also Hamilton, 2011).

A related issue is the evolution of unconventional sources of energy, pushed by new technologies in the production of shale gas and tight oil. The development of this cheaper source of energy in the US, China, India, and LAC, among others, may have important ramifications for world agricultural and food production, considering that they are all key actors in those activities: from the production of cheaper fertilizers, to some reductions in GHG emissions, to the macroeconomic impacts on real exchange rates. This is particularly so in LAC, where, in addition to traditional exporters of oil and gas, Brazil and Argentina, have potentially large reservoirs of unconventional oil and gas that can be developed.[74]

In the shorter-term the question is whether the world is going to experience a scenario similar to the 1980s and 1990s when technological developments in energy and depressed macroeconomic conditions led to a collapse in energy prices or whether the world is moving to a scenario of sustained real energy prices at levels not yet experienced in history. The answer to that question has serious implications for agricultural production, food security and poverty, management of natural resources and climate change developments. If we focus on the reference or baseline projections discussed, they suggest important costs of energy, which will affect agriculture on the production and demand side. This implies the need to place particular emphasis on energy-efficient technologies, not just in primary production but along the whole food chain. Another important aspect for agriculture is the strong growth projected for biofuel production in the IEA projections, which raises questions related to the food-versus-feed use of resources, highlighting the need to move to non-food raw material for the production of biofuels. Finally, these projections suggest that the world may be on its way to surpass the 2°C, which will produce important changes in climate and weather for agricultural and food production.

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[74] We thank David Laborde for having called our attention to the impact of the shale gas expansion in the United States on the production of guar or cluster bean in India. This crop is used to produce guar gum, a main ingredient of the hydraulic fracturing process used to extract oil and gas from oil shale. India produces 80% of world's guam bean, mostly by poor farmers in arid and semiarid areas. Exports from India have tripled, unit price has increased tenfold (see http://www.reuters.com/article/2012/05/28/us-india-shale-guar-idUSBRE84R07820120528)

5.5 STRATEGIC DIMENSION 5: CLIMATE CHANGE

5.5.1 LONGER TERM TRENDS AND SHORTER TERM VOLATILITY

Long-term data shows increasing flow emissions of GHG over the last centuries, larger concentration of those gases in the atmosphere, and rising temperatures. Changes in the gas composition in the atmosphere due to economic activities are affecting climate patterns, the hydrological cycle, and all biological activities, including agriculture. These developments are linked to the expanded use of fossil fuels, but also to changes in patterns of land use, including deforestation, and some agricultural practices. The world continues to generate a large flow of GHG (about 7 metric tons per capita of CO2 equivalent in 2005, or some 47 Giga-tons a year) that, under most projections (see previous section), will continue to increase and accumulate in the atmosphere, risking further increases in temperature (Vergara, 2012). The next Table shows some estimated probabilities of temperature increases given different levels of atmospheric GHG concentration. For example, if the earth is stabilized at a concentration of 450 ppm of CO2 (equivalent) in the atmosphere, the temperature would rise of 2°C with a 78% probability (in the late 2000s the concentration of CO2 alone –i.e. without other GHG- was already about 390 ppm; see previous Figure).

Table 23. Likelihood (%) of Exceeding a Temperature Increase at a given Equilibrium Stabilization level.

Stabilization levels (in ppm of CO2e)	2°C	3°C	4°C	5°C	6°C	7°C
450	78	18	3	1	0	0
500	96	44	11	3	1	0
550	99	69	24	7	2	1
650	100	94	58	24	9	4
750	100	99	82	47	22	9

Source: Stern, N. (2008) "The Economics of Climate Change", *American Economic Review*, 98(2), 1-37.

More recent estimates, however, suggest that the probabilities of higher temperatures have been increasing, and therefore the chances are that by 2050 and later, temperature will most likely increase by $2^{o}C$ or more (Jarvis, 2012).

The direct impact on agriculture comes mainly from changes in the mean and variability[75] of temperature, precipitation, and availability of daylight, shaping the length and quality of the growing season and water availability; the effect of CO2 fertilization; the evolution of plagues and pests linked to climate change, and changes in sea levels, among other factors (see Gornall et al 2010). Those impacts of climate change on agriculture production are highly differentiated by regions and crops. The determination of tolerance and resistance thresholds for specific crops is a complex undertaking given the non-linear relations between the different relevant variables. Furthermore, in climate change simulations, different General Circulation Models (GCM) offer diverse projections of what climate outcomes may result from the same levels of accumulation of greenhouse gases and aerosols in the atmosphere. For instance, the latest IFPRI's projections (Nelson et al, 2010) consider two completely different scenarios for climate change, one based on a model developed by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO), which tends to project a drier world with lower increases in temperature, and the other using the Model for Interdisciplinary Research on Climate (MIROC), implemented by the University of Tokyo's Center for Climate System Research, which suggests greater increases in precipitation and a hotter world on average.[76] It must also be emphasized that the uncertainties about the path of GHG emissions and about the impact on climate may not be solved by the Fifth Assessment of the IPCC currently being conducted, considering that the expanded and more sophisticated GCMs utilized in this Assessment are likely to expand, rather than narrow, the range of potential climate change outcomes (Maslin and Austin, 2012).

[75] Including extreme events such as droughts, floods, hurricanes, and similar ones, which affect the variability of the variables considered.

[76] They report some results from two other GCMs but the main simulations are based on CSIRO and MIROC.

The next Table shows the estimated impact on precipitation and temperature from CSIRO and MIROC GCMs for three of the scenarios of IPCC 4th, A1B, A2, and B1.[77]

Table 24. GCM and SRES scenario global average changes, 2000-2050

GCM and SRES scenario global average changes, 2000-2050					
GCM	SRES	Change between 2000 and 2050 in the annual averages			
	scenario	Precipitation	Precipitation	Minimum temperature	Maximum temperature
		(percent)	(mm)	(°C)	(°C)
CSIRO	B1	0.0	0.1	1.2	1.0
CSIRO	A1B	0.7	4.8	1.6	1.4
CSIRO	A2	0.9	6.5	1.9	1.8
MIROC	A2	3.2	23.4	2.8	2.6
MIROC	B1	3.6	25.7	2.4	2.3
MIROC	A1B	4.7	33.8	3.0	2.8
Note: Table 1.4 simplified from Nelson et al, 2010					

These are aggregates, but they differ significantly across geographical zones, as shown in the next Table also from Nelson et al, 2010, just for the northern and southern parts of LAC.

[77] The description of the scenarios in IPCC 4th is as follows (http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf)

"•The A1 storyline and scenario family describes a future world of very rapid economic growth, low population growth, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into four groups that describe alternative directions of technological change in the energy system.

•The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in high population growth. Economic development is primarily regionally oriented, and per capita economic growth and technological change are more fragmented and slower than in other storylines.

•The B1 storyline and scenario family describes a convergent world with the same low population growth as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

•The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with moderate population growth, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels."

A1B is a sub-scenario in A1 with balanced emissions from fossil and non-fossil energy sources, compared to other two scenarios with fossil, A1F, and non-fossil, A1T, sources.

Table 25. Climate scenario region-specific summary statistics, A2 scenario

Climate scenario region-specific summary statistics, A2 scenario				
(change between 2000 and 2050)				
General circulation model	Change in precipitation	Change in precipitation	Change average minimum temperature	Change average maximum temperature
	(%)	(mm)	(°C)	(°C)
Mexico, CA and Caribbean				
CSIRO-Mk3.0	-5.1	-54.4	1.43	1.67
MIROC 3.2	-11.5	-122	2.09	2.66
South America				
CSIRO-Mk3.0	0.8	12.4	1.61	1.51
MIROC 3.2	-4.1	-61.3	2.1	2.42
From: Table A2.3 in Appendix 2, Nelson et al, 2010				

How those changes in precipitation and temperature may translate into yield changes and agricultural production? The next Table (also from Nelson, et al 2010) present estimates for three main crops. They do not include the potential effect of atmospheric CO2 fertilization (which may help to increase yields) and the possibility of expanded pests and plagues linked to climate change (which may reduce yields).

Table 26. Biophysical effects of climate change on yields(% change 2000 climate to 2050 climate)

Category/model						
	Maize		Rice		Wheat	
	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
Developed						
CSIRO	-5.7	-4.4	-5.3	-13.1	-5.5	-3.9
MIROC	-12.3	-29.9	-13.3	-12.8	-11.6	-9.0
Developing						
CSIRO	-3.9	-0.8	-9.8	-1.1	-10.2	-4.2
MIROC	-5.3	-3.5	-11.9	0.1	-13.4	-10.4
Low-income developing						
CSIRO	-3.1	-3.1	-9.8	-0.6	-10.1	-11.8
MIROC	-3.4	-0.5	-9.1	1.6	-12.6	-18.0
Middle-income developing						
CSIRO	-3.9	-0.4	-9.8	-1.3	-10.2	-3.7
MIROC	-5.3	-4.1	-12.5	-0.7	-13.4	-10.0

World						
CSIRO	-4.2	-2.0	-9.5	-1.1	-9.9	-4.1
MIROC	-7.2	-12.0	-12.1	0.1	-13.2	-9.9
Source: Nelson et al 2010						
Note: The results are for the A1B scenario with assumed atmospheric concentration of 369 ppm						

The very different temperature and rainfall projections from the same emissions scenario produce important changes in projections: for instance using MIROC with A1B, yields for cereals in the US decline 33% in 2050 compared to the climate in 2000, and, because of that, developed countries, which, historically, have been important cereals exporters, suffer a significant decline in their net exports. With the results of other GCMs, the impacts of the same levels of GHG concentration produce very different projections of yields, production and trade.

ECLAC (2010) also discusses other estimates for specific countries and regions in LAC, which are summarized in what follows. The next Table shows the impacts of climate change estimated as an average of GCMs[78] for scenarios A2 and B2 in Paraguay.

Table 27. PARAGUAY: Changes in Yields of Main Crops and in Beef Productivity (Climate Change Scenarios A2 and B2) (Percentages)

		A2			B2	
	2020	2050	2080	2020	2050	2080
Corporate agriculture						
Soybean	-0.3	-10.0	-15.4	0.4	-15.3	-1.8
Maize	2.9	2.7	8.2	2.8	0.8	6.4
Wheat	3.5	-9.2	-12.9	-1.4	1.0	-5.4
Family farms						
Sesame	15.3	31.4	30.5	na	na	na
Beans	-1.4	10.0	16.2	na	na	na
Sugarcane	14.0	15.8	14.4	na	na	na
Manioc	16.1	21.8	21.9	na	na	na
Cotton	1.8	-6.1	-0.3	-0.9	-7.0	10.8
Livestock (Beef cattle)	4.4	-7.4	-27.1	-1.5	-16.2	-22.1

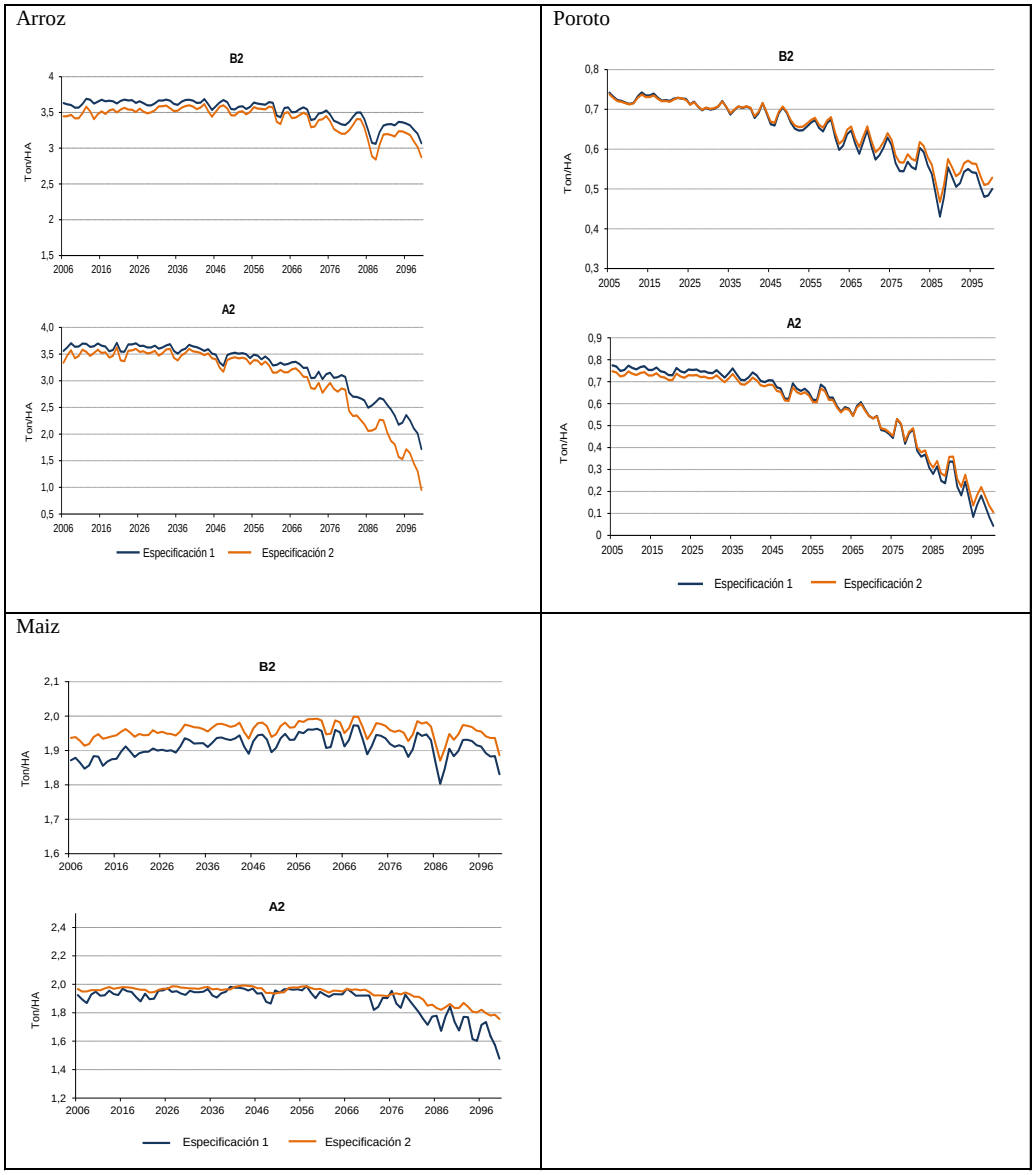
[78] There is a debate about what is the analytical meaning and practical use of averaging results from so different GCMs. The other option is to present results for the GCMs generating more extreme values (as done in Nelson et al, 2010).

Source: ECLAC, 2010					

In Scenario A2, the impact on soybeans, which is the worst affected segment of agriculture with a decline of -10% in 2050, is estimated to be equivalent to about 1.9% of the GDP in 2050. The impact in the case of Scenario B2 is even higher. In the case of wheat, the same Scenario A2 and decline of yields imply a loss of GDP of about 0.3% of 2008 GDP in 2050. On the other hand, the productivity of some crops important for family farms (sesame, beans, manioc and sugarcane) appear to have their yields positively impacted by climate change. However, livestock and cotton productivity are projected to decline (ECLAC, 2010). The following Charts (also from ECLAC, 2010) show the impact on yields for corn, beans, and rice in Central America. Beans appear negatively affected by 2050, while trends in the other crops are more difficult to discern at least until mid-century (after that, the negative impacts are more clear).

Figure 33. Central America: corn, rice and beans under B2 and A2 SRES.

Figure 1. Central America: corn, rice and beans under B2 and A2 SRES.



However, considering all impacts on agriculture, ECLAC (2010) estimates that in Scenario A2, and with a low discount rate (0.5%), losses in that sector for Central America may amount to 2.5% of the 2008 GDP in 2030 (about 3.7% in 2050). Those negative effects plus impacts on biodiversity, water, and the generation of extreme events may add up to losses of about 4.3% of the GDP in 2030 and 10.7% in

2050. Probably the strongest impact would be through an increase in the frequency of hurricanes, which have become much more frequent in the past four decades, and particularly during the 2000s.

The estimates for Argentina's yields of grains and oilseeds (ECLAC, 2010) do not show big impacts up to 2050, particularly if CO2 fertilization effects are allowed, but there may be changes in the geography of production, some sanitary problems may be reinforced, and soils may leach large quantities of organic carbon as a result of climate change combined with monoculture. More negative impacts may be felt in areas in Mendoza and northern Patagonia, currently important producers of fruits and vegetables, due to projected drops in rainfall and decline in surface and subterranean water for irrigation. In the case of Chile, estimates in ECLAC, 2010, point to declines in productivity of wheat and grape in the North but improvements in the South of the country. Future low water availability for irrigation in the north would explain the downward trend in agricultural productivity in this region, and thus generating a new pattern of land use.

In general, ECLAC, 2010, sees a long-term future with more pressure on water resources, due to changing rainfall patterns and melting of glaciers; more forest fires and heat waves; agricultural activities relocating towards cooler areas at higher altitudes and towards the southern part of South America; impacts on human health due to spread of pests, contagious diseases, and other effects of changes in precipitation patterns and water availability; impact on coastal areas of a rise in sea levels which may lead to increased coastal flooding and erosion, damages to infrastructure and buildings, losses in certain activities, such as tourism in the Caribbean, and negative effects on lowland mangroves; potentially significant biodiversity loss and declines in ecosystem services, including the gradual replacement of tropical forest by savannah in the Amazon region (with significant global impacts); and extreme events becoming more frequent and intense. These effects are mostly projected towards the end of the 2100s, and are predicated on significant increases in global temperature (above the 2^{o}C mark).

So far the discussion focused on long-run trends. However, one of the aspects of more immediate importance for agriculture is shorter-term volatility around the long-term trend (Jarvis, A. 2012). The warming of the atmosphere seems to have increased already the frequency of extreme events at the world level as well (Hansen et al, 2012). This greater volatility with a more frequent realization of extreme events may be the most important effect of climate change to consider now, considering that potentially negative consequences for yields due to increases in average temperature (the long-term trend) are projected to take place over several decades.[79] Extreme weather events such as droughts and floods are

[79] Also if CO2 fertilization effects materialize, the impact of climate change may be lower or even positive for some crops and regions. On the other hand, most of the calculations do not consider the potential impact of spreading pests and plagues, and of sea-level increases due to climate change, all of which would have negative effects on LAC's agriculture.

also calling attention to the more immediate issue of water management and water stress, which are becoming important issues in some regions in LAC.

5.5.2 ADAPTATION AND MITIGATION ACTIVITIES

Notwithstanding all the uncertainties mentioned, the agricultural sector in LAC needs to consider research and investments for adaptation to climate change in agriculture, such as the use of new varieties, different planting and/or harvesting date, as well as others strategies. Table 28 presents a list of potential strategies for adaptation to climate change.

Table 28. Strategies for Adaptation to the Climate Change in Agriculture.

I.	**Production**
	a. Crop mix and livestock
	b. New crops development
	c. Farm production and practices
	d. Expansion of arable land
	e. Changes in agricultural spatial distribution
	f. Harnessing topographical features
	g. Intensification of the use of inputs: fertilizers, irrigation
	h. Adoption of new technologies
II.	**Management practices**
	a. Income and activities diversification
	b. Water management
	c. Management innovations
	d. Timing of operations
	e. Financial management
	f. Diversification enterprises
III.	**Public policy**
	a. Insurance programs
	b. Infrastructure
	c. Assistance programs
	d. Trade policies
IV.	**Society**
	a. Research
	b. Information systems
	c. Awareness

Source: Samaniego (2012), based on Agrawala, S. and S. Fankhauser (2008)

In particular the issue of adaptation related to water management appears crucial**,** trying to achieve a better use of the water and less losses (more efficiency). Some strategies for adaptation in water management are presented in the next Table 29.

Table 29. Strategies for Adaptation to the Climate Change for Water Management

I.	**Supply side measures**
	a. Supply enhancement
	i. Building new storage capacity
	ii. Prospecting and extracting ground water in a sustainable way
	iii. Loss reduction (leakage control; conservation plumbing)
	iv. Removing invasive species from water storage
	v. Rainwater harvesting
	vi. Water transfers
	vii. Risk management to deal with rainfall variability
	viii. Water allocation (e. g. municipal vs. agricultural)
	ix. Desalinization
II.	**Demand side measures**
	a. Reducing demand
	i. Water permits
	ii. Water pricing
	iii. Taxes
	b. Efficient use of water
	c. Recycling,
	d. Changing usage patterns,
	e. Importing water-intensive products,
	f. Increased use of rainfed agriculture,
	g. Use of water markets.

Source: Samaniego (2012), based on Agrawala and Fankhauser (2008).

So far the discussion has focused on the impact of climate change on agriculture and adaptation measures. But the reverse causality from agricultural activities to climate change is important too, which leads to the consideration of mitigation issues. Worldwide, agriculture (14%) and land-use changes (12%) contribute somewhat less than 30% of all GHG emissions currently being generated. Overall, the most important sector in GHG emissions is electricity (28%), with manufacturing and construction (12%) and transport (12%) adding to the total. However, in LAC the distribution of emissions is very different with land-change use contributing 46% and agriculture 20%, while electricity and transport generate each about 8% of GHG emissions in 2005 (ECLAC 2010 based on CAIT data). Therefore, if the objective of no increasing GHG emissions beyond the level considered compatible with a 2^{o}C is to be achieved, then mitigation strategies in LAC should focus on reducing the emissions generated by deforestation and agricultural activities, especially related to livestock and rice production, fertilizer use, carbon sequestration measures through the recovery of degraded pastures, and application of minimum tillage techniques (see Vergara, 2012).

5.5.3 SOME FINAL COMMENTS

Given all the uncertainties involved in calculations of potential climate-change impacts on agriculture it seems crucial to continue working on the concept of eco-efficiency, that has been embraced for some time by CIAT for its work. The notion, starting with the World Business Council for Sustainable Development and the 1992 United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil, calls for "creating more goods and services, with ever less use of resources, waste, and pollution." CIAT research has applied the concept, stressing that "eco-efficient agriculture improves livelihoods by raising productivity and minimizing negative environmental impacts through more economically and ecologically prudent use of resources" (see CIAT, 2011) (more on this in the next section).

The possibility of applying eco-efficient approaches needs also more attention in the global negotiations on climate change, where agriculture must be included with the possibility that small farmers and developing countries receive adequate financing for adaptation and adequate credits for mitigation activities.[80]

5.6 STRATEGIC DIMENSION 6: TECHNOLOGY

There is a wide range of technological developments with potential impacts on agriculture and food security. Some of those developments are taking place clearly outside agricultural R&D as usually defined. Therefore, it is very difficult, if not impossible, to summarize developments and trends in this vast and permanently changing field. Here the objective is more limited: first, we briefly discuss what has been called "the New Biology" (Committee on a New Biology for the 21st Century, 2009) or "the Third Revolution" (MIT, 2011); then, we mentioned some policy and institutional developments; and finally, we focus on some issues relevant for a forward looking decision-making process related to

[80] Current negotiations under the United Nations Framework Convention on Climate Change (UNFCCC), showed a potential advance at the 17th Conference of the Parties (COP 17) held in Durban, South Africa, in December 2011. The expectation was that, after the Subsidiary Body for Scientific and Technological Advice (SBSTA) considered the issues related to agriculture, then some decision was going to be adopted at the COP 18 in Doha, Qatar, in early December 2012. However, as of this writing, the topic seems to have been postponed again. From the point of view of the developing countries it seems important to take an integrated approach to adaptation and mitigation issues, with emphasis on the first part; that the links to food security and the livelihood of small farmers be recognized; that adequate financing be made available for the integrated approach; that the principle of common but differentiated responsibilities (CBDR) be respected; and that decisions under UNFCCC not be utilized as trade barriers (see Murphy and Boyle, 2012).

agricultural R&D in LAC that may allow the achievement of some pre-determined objectives given the rest of the strategic factors analyzed so far. [81]

5.6.1 THE NEW BIOLOGY OR THE THIRD REVOLUTION

During the 1960s and 1970s agricultural R&D was generated by developed countries and international centers, and then was adapted by the NARs created in different LAC countries. Human capital formation and institutional structures were organized into separate compartments of traditional disciplines related to agricultural R&D. Now the potentially disruptive agricultural technologies may be developing outside the traditional agricultural R&D, and they are the result of the integration or convergence across disciplines, challenging established "silos" within organizations and scientific knowledge. This trend towards the convergence of life sciences (including those related to agriculture) with physics, chemistry, computer sciences, mathematics, and engineering, is leading to the emergence of new interdisciplinary research areas that tackle a broad range of scientific and societal problems, and is having an impact on agricultural R&D.

The US Committee on a New Biology for the 21st Century (from now on "the Committee") in a recent report has argued for a new approach whose essence "is integration— re-integration of the many sub-disciplines of biology, and the integration into biology of physicists, chemists, computer scientists, engineers, and mathematicians to create a research community with the capacity to tackle a broad range of scientific and societal problems. Integrating knowledge from many disciplines will permit deeper understanding of biological systems, which will both lead to biology-based solutions to societal problems and also feed back to enrich the individual scientific disciplines that contribute new insights" (Committee on a New Biology for the 21st Century, 2009). Similarly, MIT (2011) has talked about a "Third Revolution" where the first revolution (linked to molecular and cellular biology that helps understand cells at the molecular level, the "hardware") and the second revolution (the study of an organism entire genome, which facilitates the understanding of what drives cell processes, the "software") are combining themselves, while at the same time are converging with engineering and the physical sciences. The latter have also been changed by advances in information technology, materials, imaging, nanotechnology, optics and quantum physics, coupled with advances in computing, modeling, and simulation (MIT, 2011).

This convergence, or integration, is making it possible to predict and control the activities of biological systems in an increasing level of detail. But such convergence requires more than collaboration

[81] This approach is the same utilized in climate change models, where exploratory scenarios are developed without climate change policies, and based on that, then mitigation and adaptation policies are introduced to think about normative scenarios that try to attain certain desired objectives (see Arnell et al, 2011 that elaborate this point in relation to the new SSPs for IPCC 5th).

between disciplines; it needs true disciplinary integration (MIT, 2011) and is challenging organizational structure and models of funding and investing in science.

The Committee (2009) suggested the need to organize the work of the "New Biology" around four main global challenges:

1. Generate food plants to adapt and grow sustainably in changing environments
2. Understand and sustain ecosystem function and biodiversity in the face of rapid change.
3. Expand sustainable alternatives to fossil fuels.
4. Understand individual health.

Although all four challenges have implications for agricultural R&D, here we highlight the opportunities that the New Biology may offer for agriculture, as analyzed in the report by the Committee (2009):

a) Understanding Plant Growth

Integrating life science research with physical science, engineering, computational science, and mathematics will facilitate the development of models of plant growth in cellular and molecular detail, a knowledge does not exist yet. With that information plus an adequate catalogue of plant biodiversity, it would be possible to target genetic changes resulting in new crops and crops well adapted to their environments. This will allow a much faster and less costly development of plant varieties with the desired characteristics.

b) Genetically Informed Breeding.

The sequencing of the plant genome, its analysis, and advances in bioinformatics, allow breeders to identify the genomes and genes associated with specific and desirable traits, through quantitative mapping. Then millions of offspring can be identified and catalogued and only those with desired traits are retained, without the lengthy traditional methods that use screening after a full life cycle. This method will greatly accelerate the process of breeding plants with desired characteristics, and will allow the development of plants that can grow and thrive under local conditions and different stresses.

c) Transgenic and Genetic engineering of crops.

This is already happening, but deeper knowledge of growth processes and a more detailed mapping of biodiversity will expand the possibilities, some of which, such as improving the nutritional value of crops, have been already implemented. For instance, the Committee mentions the potential of transferring C4 photosynthetic capabilities to crops that normally use conventional C3 photosynthesis, which could increase photosynthetic rates in most of the world's food crops.

d) Biodiversity, Systematics, and Evolutionary Genomics.

New technologies in information processing, imaging, and high-throughput sequencing, among others, will help to develop a deeper knowledge of plant diversity and evolutionary biology, facilitating

the identification of genes and traits that can be utilized to strengthen current crops or develop new ones. The Committee report (2009) uses the simile of "building a fully stocked parts warehouse with an inventory control system that quickly locates exactly the right part."

e) Crop as Ecosystems.

The goal is to understand how productivity and plant growth is linked to the complex ecosystem they are part of, which include different environment parameters (temperature, moisture and light), biological parameters (virus, bacteria, fungi, insects, birds, others animals); and other interacting factors (soil and the complex microbial communities in the soil).

In summary, the Committee considers that "a detailed understanding of how plants grow, a comprehensive catalogue of plant diversity and evolutionary relationships, and a systems approach to understanding how plants interact with the microbes and insects in their environments—each of these areas is ripe for major advances in fundamental understanding and none of them can be addressed by any one community of scientists…. the result of this focused and integrated effort will be a body of knowledge, new tools, technologies, and approaches that will make it possible to adapt all sorts of crop plants for efficient production under different conditions…"

The Committee focused on biological issues, but the convergence is also happening in advances in engineering, imaging, ICT, global positioning, and computing, which allows more precise delivery of water and nutrients. Sensors and ICT permit more rapid and routine surveillance for pests and diseases, as well as have improved the ability to predict weather patterns.

In any case, coordinating the work of all those disciplines does not necessarily mean placing scientists and experts under the same organization, but requires new organizational ways for collaboration, using advanced communication and informatics infrastructures (Committee, 2009). The integration of disciplines also requires collaboration across R&D institutions in the public and private sector working on specific projects at different levels. This approach requires new forms of funding as well (Committee, 2009; MIT, 2011).

The new research areas, because they place new demands on agricultural scientists, will require significant capacity building and interdisciplinary integration in LAC and other developing countries. They also pose important institutional challenges. In particular, NARIs need to strengthen their human resource and financial management, while also better positioning themselves within the broader science, technology, and innovation policies and structures.

5.6.2 Institutional and Policy Issues

In addition to the fact that biological sciences, engineering, and information technology seem to be entering into a new paradigm of convergence or integration (as discussed in the previous section),

there are at least three other ongoing changes that are also changing the setting where NARIs must now operate, all requiring important adjustments in their operations and financing. First, the private sector – from multinational companies to producer associations – and civil society have also taken up active roles in the development and diffusion of agricultural technology, while at the same time new public actors (such as Universities) have emerged beyond the NARIs.[82] In many cases, the private sector has strongest capabilities than NARIs in modern techniques such as recombinant-DNA, genetic transformation, and functional and structural genomics, although with variations across countries. A second change is the multiplicity of demands now placed on agriculture in addition to increasing supply and alleviating poverty, which include specific consumer preferences, health and equity requirements, and environmental sustainability and climate change challenges. This requires going beyond a primary production focus to include the forward and backward linkages of the value chain, and to consider the views of a variety of social actors. The third one is the realization that the problems affecting societies require a conceptual movement from more limited R&D approaches to an innovation focus, which is a broader concept (Trigo, 2012).

All these challenges suggest that a strategy of strengthening agricultural R&D in the region must consider at least at three levels (Trigo, 2012): first, the national level of policies and institutions of the Innovation System; second, the general system of R&D and transfer; and third, at the level of the strengthening the individual NARIs. All this will imply new organizational approaches, particularly to coordinate across multiple actors and networks. Also, in many cases, individual countries in the region do not have the scale to undertake some of the R&D activities alone and there is therefore a need of expanding regional and international networks.

Finally a crucial issue is funding those activities, which includes two separate questions: what is the level of investments and what are the financing mechanisms (Trigo, 2012). Regarding the first question, it was already noted that public investment in agricultural R&D has increased somewhat, particularly over the last decade. But LAC's average ratios are well below the levels of developed nations, and a few countries, notably Brazil, account for much of the improvements, as investment has declined in the smaller and poorer countries that are most in need of agricultural R&D.

Regarding the second question, most of the funding is public and focuses on the NARIs (e.g. the INIA-Uruguay receives 60% of the total funds invested in that country; INTA-Argentina 59% and EMBRAPA-Brazil 57%; Trigo, 2012). In a similar way, the training of human resources is located in

[82] See for instance Byerlee and Echeverría 2002, where they note that although the case for public R&D continues to be strong (based on the nature of public goods and the presence of market failures), there has been a variety of new private sector advances, from multinational to farmers' organizations, in financing and carrying on R&D activities in the agricultural and food sectors.

order of importance, at the NARIs, followed by universities and other higher education institutions. At the same time, countries have developed several strategies regarding funding mechanisms, from specific allocations in the national budget to inter-institutional special funds.[83] These mechanisms should ensure the participation of the public and private actors involved through agile operational schemes and structures that allow the integration of resources and capabilities from the institutions involved (Trigo, 2012; Echeverría et al 1996).

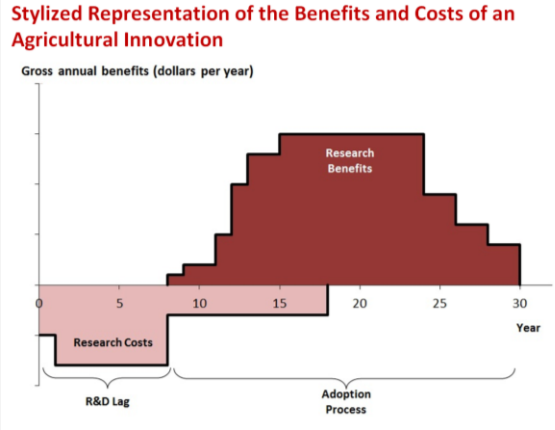
Within those broader scientific and institutional trends, in what follows we discuss three issues relevant for a forward looking decision-making process related to agricultural R&D in LAC: a) a discussion of the level of investments needed; b) the agricultural R&D priorities identified for LAC within the FORAGRO process; and c) different tools to define R&D priorities.

5.6.3 THE NEED FOR A STRONGER R&D EFFORT IN LAC

The first point to be recalled from the discussion in Section 4 is that productivity and R&D in LAC seem to be lagging behind developed countries and even some developing countries. The different indicators utilized, such as investment, intensity ratios, patents and publications related to agricultural R&D, suggest that a stronger effort in this area is needed to face LAC challenges, with its regional and global implications for food security and environmental sustainability (Pardey, 2012). In this regard, it must be emphasized that innovation in agriculture has usually developmental periods of up to 15 to 20 years, and the benefits may evolve over up to 20 or 30 years before starting to decline (Figure 34). If investments in R&D are delayed, benefits will take longer to materialize (Pardey, 2012).

Figure 34. Stylized Representation of the Benefits and Cost of an Agricultural Innovation.

[83] For an early discussion of changes in R&D financing in LAC, see Echeverria, Trigo and Byerlee, 1996



From: Pardey, 2012.

Benefits begin with a lag, approximately when the level of investment is almost at its maximum, representing also the highest adoption rates and effectiveness. It takes many years to develop a new technology before it can be effective and still remain so in the future (Pardey, 2012).

In summary, LAC has shown levels of productivity that are average in part because of lagging efforts in R&D expenditures. Improving productivity and addressing current and future challenges facing LAC's agriculture require an increase in R&D&I investments, and, because, the impact of those investments will be felt with some time lags, it is important to start now and avoid delays. If those premises are accepted, then there are a series of questions to be answered (Pardey, 2012):

1) How much to invest?
2) What production constraints operate on what crops? (i.e. drought, flood, heat, and cold tolerance; soil, slope constraints; pests and diseases; new varieties versus crop management or chemical controls?
3) In what locations?
4) What should be the balance between: short versus long term; local versus adaptive (spill-ins); crops versus livestock (and feed)?

Regarding the level of investment, next Table shows the intensity ratios for public agricultural R&D according ASTI database, for the countries with information.

	Public R&D as % of Agricultural GDP (average 2000s)
Uruguay	1.9
Brazil	1.6
Chile	1.3

Mexico	1.2
Costa Rica	1.1
Argentina	1.0
Belize	0.9
Nicaragua	0.9
Panama	0.6
Colombia	0.6
Honduras	0.5
Dominican Republic	0.3
El Salvador	0.2
Paraguay	0.2
Guatemala	0.1
Average	0.8
Median	0.9

The region should try to reach at least about 2% in intensity ratios. Uruguay and then Brazil, are the only countries that have been close to that value on average during the decade of the 2000s.

The next two sections discuss the some aspects of the setting of priorities.

5.6.4 FORAGRO CONSULTATION PROCESS[84]

During 2009, and within FORAGRO (Forum of the Americas for Agricultural Technological Research and Development), it was organized a consultation process on regional priorities for R&D&I in LAC and mechanisms to implement them. This exercise was in part related to the first Global Conference on Agricultural Research for Development (GCARD) that took place in Montpellier, France, in early 2010, organized by the Global Forum on Agricultural Research (GFAR).[85]

The consultation process started with the preparation of a reference document (Salles et al, 2009), which emphasized the regional convergence in development approaches, RDI priorities and the need to establish new institutional and financial arrangements not only for R&D but also for innovation. The main key priorities identified in that document included; a) increasing production and productivity; b) diversification and differentiation of agricultural products and services; c) improving food quality and food security; d) confronting the challenges of climate change; e) conservation and sustainable management of natural resources; f) development of agroenergy; and g) promoting institutional innovation. The process continued with an electronic consultation between 14-30 September 2009, with the participation of 550 participants from 32 countries, and a balanced representation of stakeholders. Among other things the consultation concluded that a) the priorities identified for R&D&I in LAC in the reference document appeared adequate; b) but that a development policy is much more than R&D&I

[84] Based on Salles et al, 2009, Trigo, 2009, Carriquiry and Otero, 2009, and FORAGRO, 2010

[85] Another thorough revision of R&D priorities for LAC can be found in Armbrecht I., and Avila F. (2009)

alone; c) education and access to resources and markets are critical factors for innovation to take place; d) the need to increase investment and public-private partnerships in R&D; e) the importance of developing human resources, both researchers and producers, to promote successful innovation processes. It was also emphasized the need to have a research agenda specific for the family farm; the importance integrating traditional knowledge with new technologies; and the relevance of work approaches based on participation; and the need to integrate technological and socioeconomic dimensions, and to develop a better complementarity across the national, sub-regional, regional, and international levels.

Subsequently, there was a "face-to-face" consultation during 19-20 October, at CIAT, organized by GFAR, FORAGRO, IICA, PROCISUR, and CIAT, with 70 participants. The debates emphasized a) the need that the R&D&I system generate positive impacts for marginal groups (indigenous people, peasants), which requires to work with them and not only for them; and b) the importance of expanding the participation of the private sector. Finally, there was a consolidation of the strategic priorities and recommendations by the Executive Committee of FORAGRO, in March 2010 at IICA, Costa Rica. They are attached in Annex 2.

The consultation also offered suggestions to better align the work of CGIAR with LAC's needs, and to GFAR to improve its work with LAC's institutions. The main suggestions for the CGIAR system included:

a) increasing current investments to the levels of two decades ago (close to 25%);
b) considering the challenges of family agriculture and its relationships with markets, and not only on the "poor and vulnerable";
c) strengthening the International Centers with headquarters in the Region;
d) establishing renewed alliance mechanisms based on trust, the concept of true partners, complementation rather than competition for resources;
e) implementing global projects not only on research but also for the application of knowledge by producers and the development of technological innovations in value chains and territories;
f) considering activities and crops important for LAC such as livestock and fisheries, fruits and tropical crops, including perennials, and agroforestry; and
g) taking an eco-regional approach given the variety of regions in LAC (see FORAGRO 2010)

Regarding GFAR, the main point was that it should work with the National Innovation Systems and Regional Forums (such as FORAGRO and the different PROCIs operating in LAC) to facilitate the identification of common subjects for joint action including "i) consistent mechanisms to share technical and scientific information and facilitate collaborative learning of all the actors involved in the innovation process; ii) exchange of experiences of institutional innovations (technological policies, institutional

models for RDI, public-private relationships, funding mechanisms, among others); iii) development of networks for multinational collaborative actions between institutions of the different Regional Forums; iv) support to the formation of world networks for specific research issues, in alliance with CGIAR and the technical cooperation agencies of developed countries;… v) tend towards a shared vision of agriculture within the global context, from the perspective of GFAR." (FORAGRO, 2010).

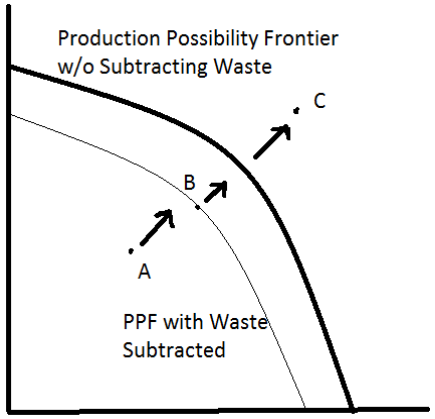
An important overall conclusion was that the greater difficulty is less the identification of priorities but how to transform them into specific activities and programs, with clear definition of impacts (Trigo, 2009; Carriquiry and Otero, 2009).

Most of the points raised in this process remain valid, and they should serve as background for the discussion of the next sections.

5.6.5 SOME OPERATIONAL ISSUES

The first thing to be noticed is that there are different approaches to increasing agricultural and food availability (Figure 35). It shows a Production Possibility Frontier (PPF) for food or agricultural production; the same PPF but with waste and losses; and three points where food and agricultural production may be located.

Figure 35. Production Possibility Frontier



Source: Authors

Without implying any priority, a first option would be to eliminate waste, moving from point B towards the attainable PPF without waste and losses (see for instance UK Foresight Report C7, 2011). Table 30 shows different levels or stages of the food supply chain and examples of waste/losses that can be reduced or eliminated.

Table 30. Generic stages of food supply chain and examples of food waste/loss

1 Harvesting – handling at harvest
*Edible crops left in field, ploughed into soil, eaten by birds and/or rodents, timing of harvest not optimal: loss in food quality
*Crop damaged during harvesting/poor harvesting technique
*Out-grades at farm to improve quality of produce or meet quality standards
2 Threshing
*Loss through poor technique
3 Drying –transport and distribution
*Poor transport infrastructure, loss due to spoiling/bruising
4 Storage
*Pests, disease, spillage, contamination, natural drying out of food.
5 Processing
5a Primary processing –cleaning, classification, de-hulling, pounding, grinding, packaging, soaking, winnowing, drying, sieving, milling
*Process losses
*Contamination in process causing loss of quality
5b Secondary processing –mixing, cooking, frying, moulding, cutting, extrusion
*Process losses
*Contamination in process causing loss of quality
6 Product evaluation –quality control: standard recipes
*Product discarded/out-grades in supply chain
*Destructive testing
7 Packaging –weighing, labeling, sealing
*Inappropriate packaging damages produce
*Grain spillage from sacks
*Attack by rodents
8 Marketing –publicity, selling, distribution
*Damage during transport: spoilage
*Poor handling in wet market
*Losses caused by lack of cooling/cold storage
9 Post-consumer –over- or inappropriate purchasing, storage, preparation, portioning and cooking
*Buying more than is needed (packsize availability, in-store promotions etc.)
*Plate scrapings and surplus food cooked and not used
*Poor storage/stock management in homes: discarded before serving
*Poor food preparation technique: edible food discarded with inedible
*Food discarded in packaging: confusion over ‘best before’ and ‘use by’ dates
10 End of life –disposal of food waste/loss at different stages of supply chain
*Food waste discarded may be separately treated, fed to livestock/poultry, mixed with other wastes and landfilled.

Source: UK Foresight Project on Global Food and Farming Futures. ‘Synthesis Report C7: Reducing waste.” 2011.

This list suggests a series of interventions to avoid waste and losses such as infrastructure improvements (cold storage, transportation), better demand and weather forecasts, consumer education, and changes in standards (to avoid discarding edible food just because of external appearances). Althouhg many of these interventions are not necessarily related to agricultural R&D as usually interpreted,there

are different pre- and post-harvesting processes in which agricultural R&D may be relevant. It was already discussed in Section 5.3 (consumption) that if those interventions are successful and objectives such as reducing waste by 50% towards 2050 are achieved (see for instance UK Foresight Report C8, 2011), then there is less need to increase production, which would be the focus of the next two options discussed immediately.[86]

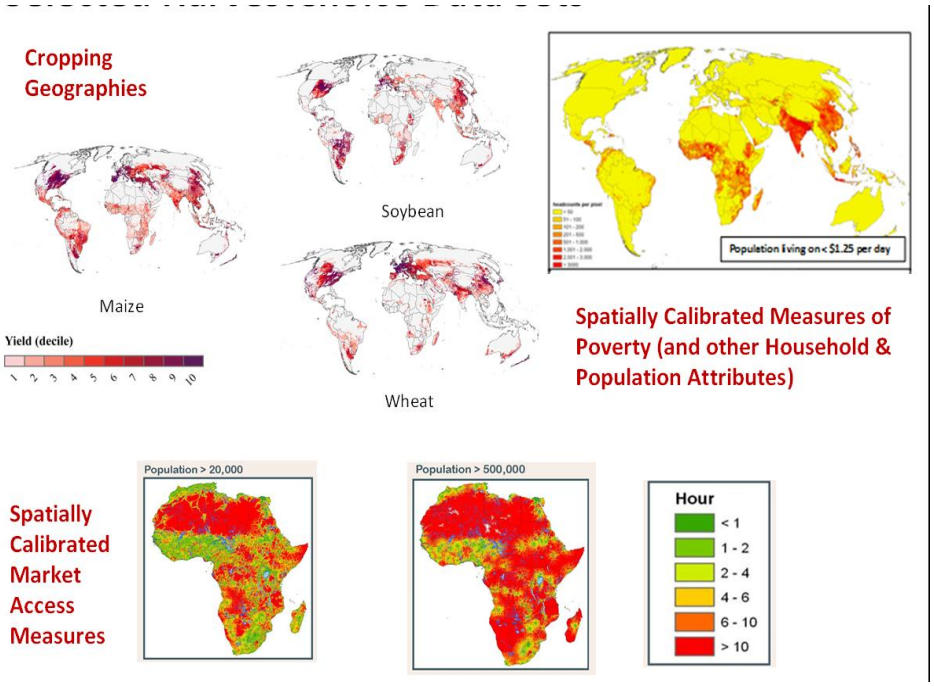
A second way of increasing production would be to ensure that "yield gaps" or "best-practice gaps" are closed across farmers, regions and countries. In Figure 35 it would mean moving from point A towards the attainable PPFs. This would require some agricultural R&D on adaptation activities, but most public sector interventions would be in other areas, such as strengthening extension services; providing health and education services in the rural areas; expanding financing and sustainable risk-management techniques; facilitating efficient and transparent markets; and ensuring access to land and water, especially for the rural poor, among other things (see for instance UK Foresight Report C5, 2011). In all these interventions it is crucial to consider gender issues and the impact on vulnerable and marginal groups.

Finally, a third way is to increase the "production possibility frontier," such as moving towards point C. This is the context in which most of the agricultural R&D is usually discussed.

There are complex decisions to be made across all those options, including a) what are the main problems to be solved, the overall implications for human well-being, and who is being affected (distributive impacts); b) what should be the overall allocation of funds to the problems/issues; c) how are they further distributed on the different approaches to potential solutions; and d) what are the complementarities between the public and private sectors to address those issues. An approach to answering those questions is to work with overlapping sets of information, such as those shown in the Figure 36 which indicates where is concentrated the production of corn, soybeans and wheat, and the largest population and poverty rates, as well as market access (Pardey, 2012).

Figure 36. Using Geographic Information

[86] As already mentioned, a recent study by the Asian Development Bank and IFPRI (Reardon et al, 2012) on food value chains for rice and potatoes in Bangladesh, China and India, shows, that contrary to common perception, waste (at least for those staple crops) seems limited (7% in the potato value chains and about 1%–2% in rice). More studies are needed to determine what is the percentage of wastage across a variety of food chains.



From: Pardey, 2012

Combining agronomic, climate, social and market information in geo-referenced maps, can help to better guide R&D efforts. However, spatial data, although is increasingly available, require a concerted effort to get them into usable form (Pardey, 2012).

Modeling approaches can also be utilized to estimate the overall implications of investing in one product or another. For instance Nelson et al 2010 model the differential impact of increasing yield trend growth[87] in different crops from the baseline values to a fixed 2% per year to 2050. The simulations include those increases in productivity in corn in USA, Mexico, China, Europe, France, Brazil, Argentina, and South Africa (which account for about 80% of corn production); in wheat in selected developing countries (India, Pakistan, Argentina, Iran, Ukraine, China, and Kazakhstan; they represented about 40% of total wheat production in 2010); and in cassava for Brazil, Democratic Republic of the Congo (DRC), Indonesia, Ghana, Nigeria, and Thailand (the top six cassava-producing countries in 2000).

Depending on the crop in which those productivity increases take place, the simulations show different impacts on prices (its own and other products), available calories, malnourished children, and net trade. The differences are driven by the role played by each crop in world and country agriculture, but also from the fact that the countries selected represented different percentages of world production, and

[87] In the IMPACT model the trend growth in yields for a particular crop is an exogenous variable called intrinsic productivity growth rate (IPR).

that a uniform increase to a 2% growth rate of each crop IPR, may represent different increases from the IPR considered in the baseline. For instance, improvements in productivity in corn, which applies to 80% of the market and for which the jump in IPR growth is large compared to the baseline, reduce malnourished children by 3.8 million persons compared to the baseline; on the other hand, in the case of wheat the beneficial effect is a reduction in 2.6 million persons, but the simulated productivity effect applies to only 40% of the world market and the increase to 2% represent a smaller jump above the exogenous IPR growth in the baseline. Conceivably, it would be possible to standardize the simulations so as to make comparisons that can suggest a ranking across products for a comparable increase in productivity (which would be different from a simulation that postulates a uniform increase to 2% for each crop IPR).

Another issue would be how much does it cost to generate comparable (however defined) improvements in productivity. That exercise was attempted in Diaz-Bonilla et al (2003). It applied to four countries/regions in LAC (Argentina, Colombia, Chile and Central America), utilizing a global CGE with 28 countries/regions and 38 productive sectors. A specific feature of the model utilized is that the level of total factor productivity (TFP) in the production functions of different primary agricultural products depended on a) government expenditures in agricultural research and b) the returns on the investment on that research.[88]

In the simulation, total public expenditures in agricultural research, the exogenous policy variable, were doubled in money value from the actual levels of expenditure in the baseline. Those additional expenditures were financed with cuts in other government expenditures or an income-tax equivalent, so that the balance of the public budget was not changed. For every year of expenditures, there were related increases in the levels of production according to the values of the IRR reported in Alston et al (2000), which accumulate over time (for changes in agricultural productivity what is important is the accumulation of expenditures in research (stocks), by opposition simply to considering annual flows; see Pardey and Bientema, 2001)

The increase in public R&D was applied to one primary product at a time, including 1) cereals; 2) vegetables and fruits; 3) oilseeds; 4) sugar; 5) bovine and other ruminants; 6) poultry and pork; 7) raw milk. The results were evaluated in terms of welfare (measured from overall consumption), total GDP, agricultural GDP, employment, and net trade balance. The results show that the ranking of investments in R&D by country and agricultural activities differ depending on the outcome variable considered, such as

[88] The values of the IRR are those that correspond to the averages reported in Table 17, page 62 by Alston J., C. Chan-Kang, M. Marra, P. Pardey, and TJ Wyatt. (2000) for each one of the geographic regions considered in the model. The ratio of R&D expenditures over agricultural GDP comes from ASTI/IFPRI/ISNAR (http://www.asti.cgiar.org/index.cfm). The model is explained in Diaz Bonilla, E., Diao, X., and Robinson, S. (2006), and, in greater detail, in http://www.ifpri.org/sites/default/files/pubs/pubs/confpapers/2003/diazbonilladiaorobinson.pdf .

welfare versus total or agricultural GDP, or employment versus net trade. For instance, in the case of Chile, if the welfare indicator is utilized, then the greatest impact of increased public expenditures in R&D comes from cereals; but if other metrics are utilized, such as total and agricultural GDP, employment and net trade, then the greatest "bang-for-the-buck" is in fruits and vegetables. Those differences are related to whether the product is oriented towards the external or the domestic market, its importance in consumption, and the links to the rest of the economy. The simulations in Diaz-Bonilla et al (2003) provide only a very rough approximation considering that the IRRs utilized are aggregates by region, and not separate by country and product. Therefore, the results reflect mainly, as mentioned, the position of the product in the structure of the economy. Better estimation of the IRR of R&D by product and country may allow a more precise discussion of the alternative impacts in terms of welfare, GDP, employment, and net trade, of allocating resources to different agricultural productions.

Even if those or other modeling exercises provide a broad view of what products may have a better payoff (however defined), there is still a further issue: none of the approaches mentioned address the separate problem of how to evaluate the range of potentially relevant technologies for a specific product (crop or livestock) or problem. That list may be long, as demonstrated by the presentation by FORAGRO already discussed, or the list of priorities for research attached in Annex 3 from Foresight C6 report.

In summary, the topics selected by FORAGRO, spatial datasets, modeling approaches, or lists of promising technologies, do not eliminate the problem that different technologies and production methods may differ not only in yields, but also a) in their impacts on the livelihood options for small farmers, the rural poor, and vulnerable populations, b) in the efficiency in using a variety of inputs, and c) in how they impact GHG emissions, local pollution, and biodiversity, among other things. Defining and using this type of complex metrics to decide across R&D&I options is still a work in process (see for instance Pardey, 2012, and CIAT, 2012). However, some of the components of that multi-criteria approach may be imposed in the end by the private sector following perceived consumer's preferences (such as carbon footprint, energy use, impact on biodiversity, fair-trade approaches, etc).

In this regard, CIAT has recently published a new study on "eco-efficiency" (CIAT, 2012) where different paths are discussed to obtain multiple objectives: a) increase productivity with lower inputs of

all types, including water and energy, and with adequate management of natural resources;[89] b) support small farmers while being gender-sensitive, and socially equitable; c) strengthen the resilience of farmers and vulnerable rural population to climate change; and d) reduce GHG emissions from agriculture while increasing carbon storage on farmland.

Therefore, from the point of view of agricultural technology R&D&I fostering eco-efficiency must consider "multiple win" technologies, i.e. where several of the multiple objectives can be attained in parallel by a given technology. A key issue is how to build adequate metrics that can capture and rank this multidimensional approach. To identify the most promising technologies it will be necessary to apply new tools and concepts such as product life-cycle analysis, green value chains, and carbon footprint measurement, with approaches based on participatory research, dynamic knowledge sharing, and capacity building (CIAT, 2011). In addition, scientific merits (such as the potential for new discoveries) and programmatic concerns (such as feasibility and readiness, logistics and infrastructure, research community commitment and readiness) may drive final decisions on agricultural R&D. [90]

To move in that direction, foresight exercises of global scenarios may be too aggregate when what may be needed are more detailed methods discussed in Section II, such as the Delphi, Technological Road Mapping or Critical Technologies. And whatever are the decisions about priorities it is crucial the institutional dimension: how to build capabilities in public and private organizations; how to establish successful cooperation and networks across public and private sectors; how to strengthen channels for transfer of innovations; how to develop shared visions by the different actors in the food system; and the establishment of regulatory frameworks for the management of natural resources such as water, biodiversity, and forests.

[89] In Keating et al (2012) they discuss at least four options for improving input-output efficiency: 1) More desired outputs and/or less undesired outputs with less inputs (example: reducing over-fertilization, such as N-fertilizer use on cereals in China, or over-irrigation such as with irrigation volumes on sugarcane in north-west Australia); 2) a lot more with a little more (raising production levels through careful targeting of production inputs such as "micro-dosing" maize or sorghum with N fertilizer in southern Africa); 3) more with the smarter use of the same (raising the effectiveness of current agricultural inputs through better targeting these inputs in space, such as via precision agriculture, or time, for example with a seasonal climate forecast; and 4) less with much less (lowering production in those regions or systems where inputs are not efficiently used, for example, because of climatic or soil reasons)

[90] For instance, Popper et al, 2000 when reviewing the setting of priorities for R&D in the US Federal system, consider the approach they call "alternative weightings" where three blocks of general categories are considered: "scientific merit," "social benefits," and "programmatic concerns." Within each area there are other sub-criteria.

6 POSSIBLE SCENARIOS FOR LAC'S AGRICULTURE

6.1 OVERVIEW OF SCENARIOS

Taking into account the previous sections, particularly the discussion on strategic dimensions, this section tries to develop a foresight framework that can support strategic planning and decision-making related to agricultural R&D policies and investments in LAC, with the aim of strengthening food security at the local, national, and global levels and to foster sustainable development, resulting in more income and employment for the poor.

Foresight studies involve a wide variety of methods, of which scenario building is among the most common. The framework described here centers mainly on scenario building, while recognizing that other methods are needed as well. It covers the period until 2030 but it also takes into account some shorter term issues. While recognizing the striking heterogeneity of agriculture in LAC, this study basically discusses the region as a whole, with the aim of developing a general framework that can later be adapted for analysis of particular sub-regions, countries, agro-ecological zones, or products.

As it was discussed in the first section, scenarios are not predictions but internally consistent and plausible descriptions of how the future might turn out to be (see for instance Porter, 2004; IPCC, 2001; and Millennium Ecosystems Assessment, 2005, among others). Those scenarios are prepared as part of some exercise of strategic planning and decision making. Policy and investment decisions that seem to be valid in different circumstances and across different scenarios are called "robust," while other options may be useful only under some circumstances.

In the last years there has been a proliferation of scenario-building, mostly related to environmental issues, but also linked to other topics. At the global level several exercises have been completed (see van Vuuren et al, 2012 and Pulver &van Deveer, 2009), including those by the IPCC Special Report on Emission Scenarios (SRES), UNEP's Global Environmental Outlooks, the Global Scenario Group (GSG), the Millennium Ecosystem Assessment, OECD Environmental Outlook to 2030, and now there are new scenarios for IPCC 5th being developed. Also, several sectoral scenarios have been produced such as those on agriculture by IFPRI (Nelson et al, 2010) and FAO (2006), which utilize quantitative approaches, and the qualitative foresight exercise undertaken by Rabobank (2010). There are also several studies on energy with alternative scenarios, including the World Energy Outlooks prepared by (IEA, 2011 IEA World Energy Outlook 201 IEA, Paris (2011)). In LAC there have been a number of

exercises as well, including those by Argentina, Brazil, Chile, and Colombia, at the country level, and PROCISUR, at the regional level.[91] In Annex 4 a summary of some foresight exercises is included.

Given the proliferation of scenario-based foresight exercises a possible question is whether the alternative futures identified have points in common, or whether the range of the expected futures is very different. If the answer is the latter, the next question is whether those differences are only the result of their specific focus, such as climate change, eco-systems services, agriculture, energy, and so on; or whether they do reflect substantially different views of the driving forces and their potential evolution, regardless of the focus. On the other hand, it may turn out to be that the range of potential futures is not that different; in this case, the follow-up question is why then to continue developing scenarios, when it is possible to build upon what has been already done.

In fact, van Vuuren et al, 2012, precisely explore those questions at the level of global scenarios. They conclude that the scenarios could be categorized in six "families," which represent the variety of possible futures analyzed in the global exercises analyzed, although noting that one possible weakness of those families of scenarios is that they do not include extreme "surprises" (except perhaps the "Breakdown" scenario of the Global Scenario Group (GSG), which analyzes a significant level of fragmentation and retrogression in the global system; see Annex 4).

The six families identified by Van Vuuren et al 2012 are: (1) the economic-technological optimism/conventional markets scenarios, (2) the reformed market scenario, (3) the global sustainability scenario, (4) the regional competition/regional markets scenarios, the (5) regional sustainable development scenarios, (6) and the businesses-as-usual/intermediate scenarios.[92] Those families of scenarios are described in the next

Table 31drawing extensively from van Vuuren et al, 2012.

Table 31. Family of Scenarios

***Economic optimism/conventional markets scenarios.** Strong focus on the mechanism of competitive, efficient market and associated rapid economic growth. Increase of free trade leading to a single global market and further deregulation and privatization that encourage efficiency and innovation. Rapid technology development and partial convergence of income levels across the world. Low population growth. Everyone benefits from globalization. Scenarios in this family tend to show high levels of environmental pressure (e.g. greenhouse gas emissions or land use), but technologic advances may remedy ecological problems even with little or no government interference. Examples of this type of scenario include the A1 scenario (IPCC), the

[91] The exercises by PROCISUR and by the governments of Argentina, Brazil, and Chile use scenarios. Colombia's prospective study follows a different approach. It must be remembered from the first chapter that the scenario approach is just one of the possible foresight methods.

[92] More recently, and not considered in van Vuuren et al 2012, the IPCC 5th process has defined at least 5 scenarios, using the axis of challenges to adaptation and mitigation, some of which could be also fitted within the 6 families identified.

Markets First scenario (UNEP), and Market Forces (GSG). A major risk of this scenario family is that the ecological and social systems could be much more fragile than assumed, and therefore, they may suffer irreversible breakdowns, leading to catastrophic outcomes.

***Reformed market scenarios.** Starts with a ''free market approach,'' as the previous one, but, recognizing the existence of market failures, it is accompanied by policies and market regulations to correct those market failures in areas such as social development, poverty alleviation and the environment. Examples of this type of scenarios include the Policy First scenario (UNEP), Policy Reform (GSG) or the Global Orchestration scenario (MA). A critical question for this scenario family is whether the type of reformist policies considered can solve poverty and sustainability problems, or major reforms of the underlying paradigm are needed.

***Global sustainable development scenarios.** In this scenario family the focus is environmental protection and reduction of poverty and inequality, through global cooperation, lifestyle change and more efficient technologies. It is assumed a high level of international coordination, with a significant degree of environmental and social consciousness combined with a coherent global approach to poverty alleviation, climate protection and nature conservation. It entails regulation of markets and pro-active policies at a world scale, based on global coordination. Examples of this type of scenario include the B1 scenario (IPCC), the Sustainability First scenario (UNEP), Great Transition (GSG) or the Techno-Garden scenario (MA). Critical issues are how to move from the current less coordinated approach to something closer to a global government, and how effective such global coordination and policies can be.

***Regional competition/regional markets scenarios.** Scenarios in this family assume a fragmentation of global governance and stalling or rolling back of globalization. Regions will focus more on self-reliance and national sovereignty, leading to diversity but also to tensions among regions and/or cultures. Countries would pay little attention to common goods. Examples of this type of scenario include the A2 scenario (IPCC), the Security First scenario (UNEP), Fortress World (GSG), or the Order from Strength scenario (MA). A key question is whether self-reliance is possible in a world where many issues are supranational, from climate change to international spread of diseases, crime, and drugs. Therefore, scenarios in this family are not optimistic with respect to global social and environmental issues. As noted, there may be more extreme scenarios of conflict as the "Breakdown" one identified by the GSG.

***Regional sustainable development scenarios.** The regional sustainability also assumes a reduction in globalization, but within a framework of less consumerism and more respect for life and the environment. Responsibilities and governance are decentralized towards local and regional decision-making structures and institutions. International institutions decline in importance. Countries and citizens act convinced of the need to solve at their level whatever social and environmental problems affect them. People and countries "think globally and act locally." Usually these scenarios envision important lifestyle changes. Examples include the Eco-Communalism scenario of the GSG, and the storylines of the B2 scenario (IPCC) and the Adapting Mosaic scenario (MA).[93] An issue is how to deal with "free riders." Another question is, again, whether global problems can be solved by the independent accumulation of individual actions at the local level (although, and different from the previous scenario of regional competition, there would be a shared set of global values that emphasize social and environmental issues).

***Business-as-usual/intermediate scenarios.** This family assumes that a plausible future can be characterized by a continuation of historical trends. Changes can, and will, occur, as in the past, when emerging problems lead to societal responses that may generate shifts in trends. Usually these scenarios are utilized as a reference for policy analysis: they are constructed with only current policies in place, and then future policies can be simulated. Examples of this type of scenario include the Current Policies

[93] Van Vuuren et al, 2012 note that these scenarios are difficult to quantify, and usually they are constructed by giving them average values for the quantity variables, which turns them more into ''intermediate scenarios'' or "business-as-usual scenarios" for the quantitative projections.

of the IEA energy outlook and the OECD Environmental Outlook.
Source: van Vuuren et al, 2012

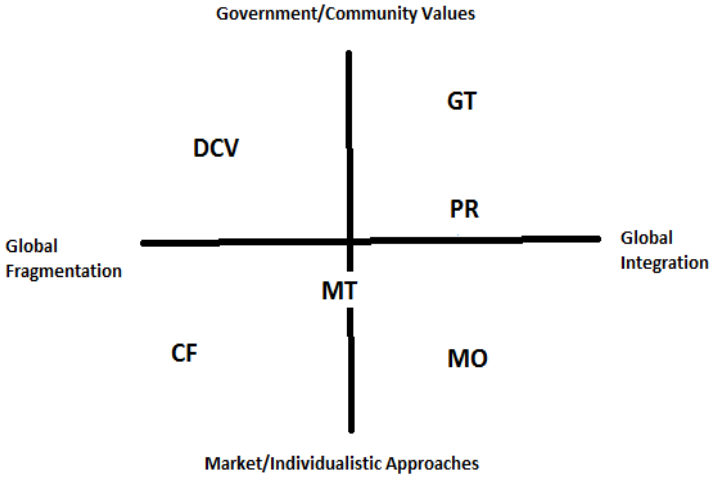
6.2 POTENTIAL SCENARIOS FOR LAC'S AGRICULTURE AND R&D ACTIVITIES

Using a common set of families of scenarios has advantages and disadvantages (van Vuuren et al, 2012). The advantages are that it helps with comparisons across reports and ensures that new studies can add further information within a common framework. The disadvantages are that it may reduce creativity and be limiting in terms of the envisioning possible futures (including extreme events). In any case, it seems an empirical fact that existing scenarios in very different exercises tend to cluster around those six families (with possibly positive and negative examples within the same family)[94], although this should not lead to the claim that all scenario families are feasible, and there may be other scenario families as well (van Vuuren et al, 2012).

In what follows we build alternative scenarios for agricultural R&D in LAC, utilizing a framework consisting of two axes, as indicated in Figure ????. The vertical axis represents the level of government intervention and prevalence of community values versus a market orientation and more individualistic ethics. The horizontal axis indicates the choice between continued global economic and political integration versus reversion to a more fragmented system of national governance with less economic integration and institutional coordination.

Figure ??? Dimensions to Define the Scenarios Utilized

[94] For instance, van Vuuren et al 2012, give the example of the family of "economic optimism" which may lead "to successful variants assuming that environmental feedbacks are small – but rather unsuccessful, disaster scenarios if feedbacks are strong."



This analysis suggests six main scenarios, that broadly follow the types of families discussed by van Vuuren et al, 2012, but with several changes and extensions to fit the sector (agriculture), region (LAC), and issue (R&D&I) of interest:

1. Market Optimism (MO)
2. Policy Reform (PR)
3. Global Transformation (GT)
4. Decentralization with Convergence in Values (DCV)
5. Conflictive Fragmentation (CF)
6. Muddling Through (MT)

Some of the main issues and story-lines are summarized in the following Table. The columns referring to Globalization and Governance, Population, Growth, Energy (Technological change), Climate Change, and Food Consumption (values and habits), refer to global issues. On the other hand, the columns on Poverty and Income Distribution, Land Use and Water, Agrarian Structure, Other Economic Actors in the Food Supply Chain, and Agricultural R&D, focus on how the scenarios may unfold in LAC.

Table 32. Possible Scenarios

	Globalization and Governance	Population	Growth
Muddling Through	Economic integration slows down or gets stalled. World operates with current levels of global policy coordination or less. Within a general trend towards democracy in several developing regions, there is a variety of political regimes, including many non-democratic ones.	UN middle projection. Aging process continues, with some impact on food consumption and the growth-sustaining demographic dividend.	Middle (global growth 1.5-1.9% per capita). Slow growth in developed countries during the next 5-10 years, affecting global growth.
Market Optimism	Economic Integration. Current levels of global coordination. A somewhat stronger general trend towards democracy in developing regions (but still a variety of political regimes).	Middle/Low projection. Aging process continues, with impact on food consumption and demographic dividend	High (global growth 2.1-2.5% per capita). Quick recovery from current crisis based on market forces.
Policy Reform	Economic Integration. Reinforced global coordination. Stronger general trend towards democracy in developing regions.	Middle/Low projection. Aging process continues, with impact on food consumption and demographic dividend.	Middle/High (global growth 1.8-2.1% per capita). Intermediate recovery from current crisis.
Global Transformation	Economic Integration. Significant global coordination. Movement toward more participatory democracy.	Middle/Low projection. Aging process continues, with impact on food consumption and demographic dividend.	Middle/Low (global growth 1.4-1.7% per capita). Quick recovery from current crisis based on coordinated policies.
Conflictive Fragmentation	Reduction in economic integration and in global coordination. Variety of regimes with democracy losing strength globally.	Middle/High projection. Less impact of aging process because of higher population growth in the next decades.	Low (global growth not more than 1.3% per capita). Protracted economic and political crisis.
Decentralization with Convergence in Values	Reduction in economic integration, but regions manage affairs in a collaborative manner. Participatory democracy.	Middle projection. Aging process continues with some impact on food consumption and demographic dividend.	Middle/Low (global growth about 1.3-1.5% per capita). Slow recovery from current crisis.
	Energy (Technological change)	**Climate Change**	**Food Consumption (values and habits)**
Muddling Through	Middle/Low. Shale gas has some impact. Intermediate development of renewable sources of energy. Energy efficiency improvements continue at historical trends	Challenges for mitigation and adaptation. World in global trajectory to reach increase of 2oC in temperature by 2050. Greater recurrence of extreme events.	No food regulation of carbon footprint, energy use, and similar, in industrialized countries, that may affect meat and long-distance food trade. No public regulation of waste. Intermediate convergence to higher meat consumption in developing countries
Market Optimism	High, assumed to come from market mechanism: higher prices allow development of more renewables and lead to greater energy efficiency.	Challenges for mitigation, but not for adaptation. Risk of reaching climate tipping points that may not be solvable by technology. World in global trajectory to go above 2oC by 2050. Greater recurrence of extreme events.	Same as above, in part because technological change in energy reduces costs. Faster convergence to higher meat consumption in developing countries

Policy Reform	High/medium, coming from policy reform. Some carbon pricing leads to more efficiency, more renewables and gas replaces larger share of coal (in part as the "golden-era-of gas" scenario of IEA	Combined intermediate efforts at mitigation and adaptation. World in global trajectory to stay below 2oC by 2050. Perhaps less recurrence of extreme events.	Some regulation of carbon footprint, energy use, and waste, with impacts on meat consumption and long-distance food trade. Intermediate convergence to meat consumption in developing countries
Global Transformation	High, resulting from policy reform (e.g. carbon pricing). Coal eliminated in energy matrix, higher efficiency, and larger share of renewables. Shale gas may be more constrained by environmental considerations.	Strong mitigation efforts, reducing needs for adaptation. World in global trajectory to stay at or below 2oC by 2050. Probably less recurrence of extreme events.	More regulation of carbon footprint, energy use, and waste, with significant impacts on meat consumption and long-distance food trade. Intermediate convergence to meat consumption in developing countries, but lower meat consumption in industrialized countries
Conflictive Fragmentation	Low change. Similar energy matrix as now, with perhaps coal regaining largest share in energy matrix, displacing oil (as in scenario of "Current Policies" of IEA)	Significant challenges for adaptation and mitigation; although growth is low, population is middle/high and there is no global collaboration. Greater recurrence of extreme events, and even risk of catastrophic global climate events. World in global trajectory to go above 2oC by 2050.	Variety of approaches.
Decentralization with Convergence in Values	Uncertain.	Challenges for mitigation and adaptation worked out at local level. Not clear the trajectory to global temperature. Still, probably recurrence of extreme events.	More regulation of carbon footprint, energy use, and waste, with impact on meat consumption and long-distance food trade. Intermediate convergence to meat consumption in developing countries, but lower consumption in industrialized countries
	Poverty, Income Distribution, and Nutrition	**Land Use and Water**	**Agrarian Structure**
Muddling Through	Urbanization of poverty. Some reduction of poverty. Inequality continues. The "double burden of malnutrition" affects LAC population.	Continuation of historical rates of deforestation. Biodiversity losses. Water challenges	Concentration of land, with instances of "land grabbing." Decline of small farmers and family farm.
Market Optimism	Urbanization of poverty, but more resources to finance social plans. Poverty reduced by growth but inequality persists. The "double burden of malnutrition" affects LAC population, but it is more important the impact of overweight and related diseases.	Continuation of historical rates of deforestation. Water challenges	Stronger concentration of land, with instances of "land grabbing". Decline of small farmers and family farm.

Policy Reform	Urbanization of poverty, but more resources to finance social plans. Poverty and inequality reduced by growth and social plans. Consumer education, safety nets, and better preventive approaches in health reduce the "double burden of malnutrition" affects LAC population.	Slowing down or eventually stopping deforestation. Water efficiency measures	Public programs in support of small farmers and family farm. More regulation of "land grabbing."
Global Transformation	Better planning of cities and urbanization, with improved services. Reduced poverty and inequality. Consumer education, safety nets, and better preventive approaches in health control the "double burden of malnutrition" affects LAC population.	Reforestation. Strong water efficiency measures	More support for family farms and small famers.
Conflictive Fragmentation	Urbanization of poverty. Poverty and inequality do not improve. LAC population suffers from the "double burden of malnutrition" affects LAC population.	Continuation of historical rates of deforestation. Water challenges	Concentration of land, with instances of "land grabbing" leading to conflicts across countries. But because of low world growth and lack of global integration, there may be less incentives for commercial agriculture, and small farms expand as defensive option for the rural poor.
Decentralization with Convergence in Values	Better planning of cities and urbanization, with improved services. Lower growth affects poverty alleviation. LAC population suffers from the "double burden of malnutrition" affects LAC population, although more healthy lifestyles help reduce somewhat the extent of the problem in some countries.	Slowing rate of deforestation. Water efficiency.	Not clear
	Other Economic Actors in the Food Supply Chain	**Agricultural R&D**	

Muddling Through	Continues "supermarket revolution" favoring larger farmers, farmers with assets and capabilities. Some integration of smaller farmers through cooperatives. Agricultural technology on commercial products generated by multinational corporations	Muddling-through scenarios combine components of the others scenarios. Increasing separation of R&D activities in the public and private sectors. The commercial sector will not necessarily internalize the costs of sustainability, while the public sector may focus on a shrinking group of small-scale producers without integrating scientific disciplines and without focusing on innovation. Weak global and regional networks devoted to multicountry challenges and to help small and poor countries.
Market Optimism	Continues "supermarket revolution" favoring larger farmers, farmers with assets and capabilities. Some integration of smaller farmers through cooperatives. Agricultural technology on commercial products generated by multinational corporations	Increasing separation of R&D activities in the public and private sectors as in Muddling Through. But there is optimism that R&D activities, although not coordinated and not part of global or regional networks, will nontheless reach efficient (although not necessarily equitable) solutions for agriculture and the environment. .
Policy Reform	Continues "supermarket revolution" but with standardization of contracts with small farmers, more public support for public-private agreements. More funds for public R&D&I in support of small farmers, diversified crops and livestock activities, and mitigation and adaptation R&D in agriculture.	Public sector policies and investments could moderate market and coordination failures, leading to greater convergence in R&D efforts and better enabling it to address different types of producers and problems. Some global and regional networks to attack multi-country challenges and to help poor and small countries to overcome scale problems in R&D.
Global Transformation	Reconfigured food chain. More funds for public R&D&I in support of small farmers, mitigation and adaptation R&D in agriculture, low-energy and low-carbon agriculture.	Public sector policies and investments lead to collaboration within national and international public sector, and with the private sector. Strong international and regional alliances to help poor and small countries with R&D activities. Convergence in R&D efforts to address different types of producers and problems. , generate public goods, integrate adaptation and mitigation activities in agriculture in wasy that are fair to small farmers and developing countries, and facilitate integration across scientific disciplines.

Conflictive Fragmentation	Supermarket revolution stopped in its international dimensions, due to trade barriers and de-globalization. Local dimension of food chain continues favoring larger farmers, farmers with assets and capabilities. More fragmentation of agricultural technology activities.	Market segmentation together with political fragmentation at the global and regional levels lead to greater divergence across countries and economic actors in R&D for agriculture and agro-industry. Divergent priorities across countries and between public and private sectors. Negative effects on agricultural productivity and the environment.
Decentralization with Convergence in Values	Not clear	As in the previous scenario, market and political fragmentation at the global and regional levels lead to greater divergence across countries and economic actors in R&D for agriculture and agro-industry. However, because there are shared values, priorities across countries and between public and private sectors may not diverge that much, mitigating the negative effects on agricultural productivity and the environment that may come from the fact that R&D are not better coordinated.

These are qualitative storylines that may require further quantification. In what follows some quantitative projections are summarized. They tend basically to reflect baseline or intermediate scenarios, sharing some aspects of both Muddling Through (with regards to globalization and climate change policies, for instance) and Market Optimism (relatively higher economic growth rates and expectations of technological change), and depending of the future policies projected, also some aspects of Policy Reform.

6.3 MODELS AND PROJECTIONS

The projections discussed are based on Rosegrant (2012), van der Mensbrugghe (2012), and Zahniser (2012). In what follows some of the main points are summarized.

a. The highest rates of GDP growth will be concentrated in developing and emerging countries such as South East Asia, South Asia, Africa and Latin American and the Caribbean. In general all models consider world per capita growth rates above 2% annually
b. Population growth rates will decline, but absolute levels will continue increasing. Most of the increase will happen in Africa and South Asia (Zahniser, 2012 and Rosegrant, 2012).

c. The growth rate of food consumption will decline with respect to the historical values, but absolute values will continue to increase. Industrial countries will still have larger per capita food consumption per day in 2050, followed by Near East-North Africa, East Europe, and LAC. East Asia and SSA will show the lower levels of per capita consumption of calories, but that will be about 20-25% higher than in mid-2000s (van der Mensbrugghe, 2012).
d. The growth rate of agricultural production will be below historical averages, both globally and regionally, but the absolute value will continue to grow (van der Mensbrugghe, 2012).
e. The increases in production will result mostly from increases in yields, with a far smaller contribution of land expansion. Increases in land will happen mostly in SSA and LAC (Rosegrant, 2012, van der Mensbrugghe, 2012).
f. Agricultural yields present a different patterns depending of the region and crop, but the general trend on yield growth for cereals and oilseeds is declining. In LAC Brazil will perform better than Argentina, Mexico and other countries, due to the higher expected levels in R&D investment (Rosegrant, 2012).
g. Prices will stay relatively high for cereals (corn, wheat and rice) and meats (pork, chicken and beef). Prices of corn would increase up to 55%, linked to biofuels and meat demand. Strong increases are also projected for pork and poultry, based on the strong demand projected for proteins (Rosegrant, 2012, Zanhiser 2012).
h. LAC as a whole continues to be an important net agricultural and food exporter, reinforcing LAC's comparative advantage (van der Mensbrugghe, 2012). But there will continue to be important differences within the region. Both cereals and meat will have net positive balances in Argentina and Brazil. On the other hand, Mexico will be a net importer of cereals, and, marginally, of meat. The rest of LAC will be a net importer of cereals and oilseeds, but a net exporter of meat (Rosegrant, 2012).
i. USDA projections (towards 2020s) show increasing exports of fruits and vegetables from LAC to the US, and estimates that Brazil will become the main world meat exporter, but still will be a net importer of cereals towards 2020 (Zahniser, 2012).
j. USDA also notes the important uncertainties related to meat consumption preferences (Zahniser, 2012)
k. In general, LAC will show lower rates of population at risk of hunger (Rosegrant, 2012) or undernourishment (van der Mensbrugghe, 2012) that other developing regions, but with differences across countries (Rosegrant, 2012).

7 POSSIBLE IMPLICATIONS FOR LAC AGRICULTURE AND R&D

In this section some possible implications of the previous analysis of the history, strategic dimensions, and scenarios are outlined. The conclusions offered are relatively broad statements, in line with the extensive nature of this exercise. But it is expected that the foresight framework and the conclusions presented here can help to conduct more detailed analyses at the level of sub-regions, ecological zones, countries, agricultural value chains and specific products, which can deepen and made more specific the implications for agricultural R&D in LAC.

7.1 A DUAL ROLE AND AN ENORMOUS CHALLENGE: THE NEED TO DOUBLE R&D INVESTMENTS

The historical analysis has shown that LAC as a whole (although with country variations) has somewhat outpaced global growth in food availability (measured in calories, proteins, and fat per capita, and that the region's agricultural production (valued in constant terms) has increased its share of global output from about 10% in the 1960s to about 13% in the 2000s, becoming slightly larger than that of either, the European Union, or USA plus Canada and has exceeded that of India by almost 30%.

Also, during the 2000s, LAC became the world's main net food exporting region, reflecting strongly, but not exclusively, the net trade surpluses generated by Brazil and Argentina. As the world's largest net food exporting region, LAC is playing a vital role in stabilizing global food prices and supplies. Quantitative simulations tend to confirm that the region will continue to influence global food security in the coming decades.

The noticeable gains in LAC's agriculture, though driven in part by productivity improvement, also resulted from significant expansion of agricultural area over the last half century. As mentioned, the region has contributed a third of the global increase in agricultural land (crops and pastures) since the 1960s and accounted for two-thirds of global deforestation from 1990 to 2010. Unsurprisingly, land-use change contributes more to LAC's greenhouse gas (GHG) emissions than any other source, though the region's emissions are comparatively low.

Those trends are worrisome considering that rapid land-use change is putting pressure on LAC's other role as the developing world's biggest provider of global environmental goods, including biodiversity and oxygen. Several major staples (such as beans, cassava, maize) have their centers of origin

and diversity in this region.[95] Out of the ten countries in the world with more biodiversity, six, and the top two (Brazil and Colombia), are in LAC, according to indices developed by the World Resources Institute.

This path of land-change use cannot continue without important negative effects on forestation, biodiversity, the generation of oxygen, and other global environmental "public goods" produced by the region. As it was noted, in some countries it seems possible to convert pastures used for extensive livestock production into crop production without affecting forests. In others, however, maintaining current levels of expansion of agricultural land would pose serious environmental challenges.

All this suggests a global dual role for LAC: on the one hand, it is a key component of world food security, by providing the largest margin of net world food exports and thus helping to stabilize world prices and quantities (role that all projections indicate that will continue in the future); on the other, it is an important provider of global environmental goods as well. Agriculture and food production in the region is at the intersection of both roles, with significant trade-offs between them. Therefore LAC has to respond to national socio-economic and environmental challenges, while also being an eco-efficient global agri-food supplier, whose performance is crucial for global food security and environmental sustainability.

This crucial dual role of LAC at the global level is not always fully appreciated, and therefore LAC, because of somewhat better socio-economic and agri-food indicators than other developing regions, tends to appear lower in the priorities for allocation of resources within the international community.

One of the implications of the analysis is that for LAC to be able to play that important global dual role effectively investments in R&D for development in the region, both from national governments, but also from the international community, must increase along the whole agricultural and food chain. The average ratio of agricultural R&D intensity, which currently stands at just 1% of agricultural GDP, should at least double. Otherwise, one or the other of those roles will suffer.

7.2 AGRICULTURE'S SHIFTING TERRAIN AND R&D PRIORITIES: MORE THAN STAPLE CROPS

Changes in LAC agriculture have taken place against a background of large inequalities in land tenure, with small farms fragmenting further and large landholdings expanding, all of which is squeezing out family farms and local communities with traditional production structures and knowledge. Land-related conflicts continue, and they mix with drug and guerrilla violence in some countries. Greater concentration at the top of LAC's agrarian structure and increased fragmentation at the bottom is

[95] CIATs gene bank, coupled with its advanced biological sciences and crop applications experience and capacity, constitute a regional advantage of a portfolio of strategic advances in agricultural and biological science, technology and innovation (STI) for applications/extrapolations to/in other areas such as Sub-Saharan Africa and South East Asia.

prompting the R&D efforts of the public and private sectors to diverge. Therefore, technological levels vary significantly between and within countries and across producer groups. Also, agricultural production has diversified, as reflected in the changes in exports already mentioned. A clear difference in the structure of LAC's agricultural production compared to other developed and developing regions is the importance of livestock.

Other actors in agricultural production, processing, and marketing have also seen important shifts in the provision of technology and inputs, in the processing sectors of the agriculture and food value chains, and in the operation of supermarkets. Changes in the region's agriculture are driven mainly by the private sector – from farmers to large companies producing agricultural inputs and processing and marketing agricultural and food products. The private sector acts according to market approaches based on estimated costs and benefits. It would not consider and price externalities and alternative social objectives, without adequate public policies, institutions, and investments related to agricultural R&D.

Poverty in LAC has declined in recent decades, becoming concentrated in urban centers, as rural populations and agricultural employment have fallen significantly. The role of women in agricultural and rural markets has also shown a diversity of situations along the whole food chain, depending on countries and products. Although hunger has also been declining, the region still has to confront a "double burden" of malnourishment in which under-nutrition (albeit reduced compared to previous decades) now coexists with excesses in consumption of sugar, fats and salt, leading to chronic illnesses such as diabetes and high blood pressure.

In view of the diverse and changing agrarian structures and food markets and the urbanization of poverty in LAC, agricultural R&D in the region faces complex challenges: it must widen its scope beyond the staple crops produced by smallholder farmers if the most pressing issues for global food security and environmental sustainability playing out in the region are to be addressed. Relevant topics for LAC, where local poverty, global food security, and overall environmental sustainability intersect include sustainable livestock production, agro-forestry, and fruits and vegetable production. R&D efforts in the region must pay particular attention to those issues.

7.3 ALONG WITH HIGH-GROWTH, HIGH-DEMAND SCENARIOS, OTHER LESS BUOYANT FUTURES SHOULD BE CONSIDERED

Going forward, there are large uncertainties related to GDP growth, population aging, changes in consumption pattern, the impact of climate change, and institutional challenges at the world, regional, and national levels. However, most scenarios tend to project a world with high rates of economic growth

where demand for food and agricultural goods is strong, leading to higher food prices in real terms.[96] Still, the analysis of strategic dimensions and scenarios shows that there are combinations of events that may point to less rapid expansion in demand and, therefore, to real prices lower than projected. These scenarios consider in the short- to medium-term a very slow world recovery from the current financial crisis, and even a relapse into recession at the global level.

In this line of thinking, a near-future concern is the potential impact of the current financial crisis on the size and composition of the European Union and the Euro, with the multiple and negative ramifications for the world economy of the fiscal and banking problems there, and even more concerning if the Euro zone losses members casting doubts on the Euro itself. A second and more general issue is the evolution of global economic imbalances and the potential for currency and trade conflicts, in a context of weak global economic institutions that may not be able to engineer the global rebalancing needed to sustain healthy growth going forward.[97]

Even if this downturn is properly managed, industrialized economies will face a relatively protracted period of low growth, at least during the first half of the 2010s, because of a) the need of consumers in industrialized countries to improve their balance sheets (which will constraint consumption); b) the fiscal and monetary restrictions in many industrialized countries after the strong expansionary policies followed in the late 2000s; and c) the weakness of the financial and banking sector emerging from the crisis. All in all, expenditure adjustments in the public and household sectors in industrialized countries, along with less abundant credit, will lead to lower growth. In particular, rebalancing the U.S. economy requires lower trade deficits: therefore, the world will not have the consumption engine that propelled growth during the past two decades, and it is not clear what can replace it.

As argued before, the model of growth based on a restructuring of previous "dirigiste" economies (a supply-side shock), that began to produce for world markets, particularly the United States, in the context of expansionary monetary policies, that accelerated global demand and made the US the "consumer of last resort" (demand-side accommodation), may not be repeated. The question is what growth engine (beyond the mechanical churning of convergence models) can replace the one that

[96] As it has been shown in other places (Díaz-Bonilla and Ron, 2010, and Díaz-Bonilla, 2011) part of the price increases is related to the devaluation of the US dollar, the currency in which the prices of commodities are usually quoted. If prices are presented in a more stable measure of value, such as Special Drawing Rights, the composite currency utilized by the IMF, the nominal price increases of recent years are clearly smaller than what appears when commodity prices are quoted in US dollars.

[97] For instance Patrouilleau et al (2012) place special emphasis in their study for Argentina's INTA in the process of emerging from the current crisis, and the importance of the bilateral relationship between USA and China in that process, with different types of scenarios depending on collaborative and confrontational configurations between those two countries.

sustained the expansion of the global economy during the past decades. This slower-growth scenario would be reinforced by an increase in conflicts that halts or even rolls back world economic integration, as in the Conflictive Regionalization scenario (and even perhaps in the Muddling Through scenario). In these scenarios, negotiations related to climate change would also get bogged down.

If lower growth is combined with the impact of population aging on food consumption, with a decline in meat consumption in industrialized countries and a pattern of meat consumption in developing countries that do not convergence with richer countries at the rates expected, and with a strong movement towards reduction of waste (as in the scenarios of Global Change and Collaborative Regionalization, and partially in the Policy Reform scenario), then it may not be necessary to increase production by the 60-70% usually mentioned, and prices may not be as high as expected.

On the other hand, this lower growth may have some positive consequences: there may be less pressure on LAC forests, and the current process of land concentration may slow down, opening opportunities for the expansion of family/small farms.

Overall, although it may be appropriate to maintain the high-growth, high-price projections as a benchmark, it would also be prudent to consider (and run quantitatively) less optimistic scenarios, such as a combination of Muddling Through and Conflictive Regionalization. In these scenarios, slow recovery from the current global financial crisis and the exhaustion of key sources of growth in recent decades combine with continuing trade and financial conflicts (most likely slipping over into geopolitical tensions as well) that would undermine world economic integration, and with lower food consumption as a result of aging populations and a serious movement to reduce food waste. Of course, these projections suggesting softer food demand growth may face in the future a more constrained supply response, if climate change developments end up being more negative than current estimates or if the technological promises of the new convergence of sciences do not materialize. In that case a less buoyant demand projection will be compensated by a lackluster supply response, with a muted impact on price the projections.

Other scenarios discussed here, such as Market Optimism, Global Change, and Collaborative Regionalization, seem less likely in the short- to medium-term.

7.4 AGRICULTURAL R&D IN LAC MUST LOOK AT THE LINK ENERGY-AGRICULTURE IN GENERAL, INCLUDING BIOFUELS, BUT TAKING A BROADER VIEW.

Usually, when discussing the issue of energy and agriculture, the main topic appears to be biofuels and the competition food-feed-fuel (particularly in the case of biofuels based on corn and soybeans). The usual R&D recommendations focus on finding non-food raw materials for the production

of biofuels (such as using lignocellulosic materials and other non-edible sources in second and third generation of biofuels) (see for instance Committee, 2009). Another important issue is the use and recycling of biomass and organic material as a source of energy in agricultural production. Overall, the challenge is to develop production models in which small and family farmers can participate in agro-energy production, and integrate those models into local development strategies (see for instance the priorities for agricultural R&D included in the presentation by FORAGRO, 2010). These are important priorities for agricultural R&D.

At the same time, the analysis in the previous sections, however, suggests the need to expand the analysis related to energy and agriculture to more than biofuels and biomass. Increasing energy efficiency and energy capture and recycling in the whole agricultural production, processing, and transportation value chain, is a "multiple win" approach by reducing costs and decreasing the emissions of GHG related to agricultural activities and food consumption.

In the not distant future, the requirement to generate those energy efficiencies may also come from public policies and/or private standards (based on consumers' preferences) that mandate the disclosure of the energy and carbon footprints of food products, with the aim to reducing them (such as would be the case in the Policy Reform, Global Change, and Collaborative Regionalization scenarios).

At the macroeconomic level, it is useful to recall the previous discussion about the cycle of the second part of the 1970s and early 1980s in which prices of energy and agricultural goods moved in synchrony. In general, world prices of oil and agricultural commodities have been correlated since at least the 1970s, but this phenomenon seems to have been accentuated more recently because of what has been called the "financialization" of commodities (i.e. commodities becoming investments options, in part as hedges against inflationary developments). The strong global growth cycle during the 1960/1970s led to commodity price spikes in the 1970s, but it was then followed by a collapse in oil prices due to the global recession of the early 1980s, the debt crises in developing countries, and technological innovations such as the development of deep sea oil extraction in the North Sea, which weakened OPEC's market power to set prices. In the agricultural sector, changes in agricultural trade policies in industrialized countries and the recessionary global macroeconomic conditions also led to the collapse of the prices of agricultural goods in the second part of the 1980s. In that context the continuous advance of the Green Revolution was also supported by lower oil prices, which helped to keep fertilizers price and energy costs in general under control. Now the world has just ended a second period of accelerated growth, and the future evolution of energy (and oil) prices is debated, with very different implications for world agriculture.

There are many unknowns. As it was already discussed, the traditional economic view is that except for short-term supply side shocks (such as geopolitical turmoil in producing countries), higher prices will generate the investments and the technological response to expand supply in the medium- to

long-term. On the other hand, the geological view is that there may be some "hard supply constraints" that will be difficult to overcome, and at some point oil production will peak and then decline.

It was shown that the International Energy Agency, the US EIA and some IMF studies suggest prices that in real terms are close to double the average of the levels during the previous two price spikes, and are 10-40% above the high of 2011. All this raises important questions marks regarding the sustainability of growth rates for the global economy.[98]

At the same time, as argued, the evolution of unconventional sources of energy, pushed by new technologies in the production of shale gas and tight oil, are changing the energy landscape and reducing gas prices in some large markets. Several of the countries with potential for the development of unconventional sources of energy, particularly shale gas, are also important players in the global food system, such as US, China, India, and LAC. The development of this cheaper source of energy in those countries may have important ramifications for world agricultural and food production from the production of cheaper fertilizers to the potential Dutch-disease effect brought about by larger exports of energy. This last effect may be particularly important for LAC, where exchange rates are more market based and where there are several actual or potential exporters of energy, including countries such as Brazil and Argentina, which have potentially large reservoirs of unconventional oil and gas that can be developed.

In summary, it is important to monitor the global scenarios to determine whether the world is going to have a similar cycle as in the 1980s and 1990s when technological developments in energy and depressed macroeconomic conditions led to a collapse in energy prices or whether the world is moving towards a scenario of sustained real energy prices at levels not yet experienced in history. In the particular case of LAC a main unknown is the evolution of non-conventional energy sources, such as shale gas and oil. The answers to those questions, which have important implications for agricultural production, food security and poverty, management of natural resources and climate change developments, require a more systematic and integral view of the complex links between energy and agriculture.

[98] OPEC projections, on the other hand, estimate real prices in line with the average of the 2000s, which is still higher than the average for the last four decades, but significantly lower than the other projections.

In the case of agricultural R&D priorities in LAC there are at least two implications. First, it is important to consider energy topics that include but go beyond biofuels. Second, R&D activities should also focus on energy efficiency, looking at the whole food value chain, and not only at the farm level.[99]

7.5 Regarding Climate Change, the more immediate concerns are extreme events and water stress.

The energy projections discussed before suggest that the world may be on its way to surpass the 2°C increase in the average temperature by 2050, which will produce important changes in climate and weather patterns, affecting agricultural and food production. While this trend is obviously worrisome, there is a more immediate problem for agriculture: the fact that weather volatility has gone up around such trend (Jarvis, 2012), with the warming of the atmosphere increasing already the frequency of extreme events at the world level (Hansen et al, 2012). This more frequent realization of extreme events may be the most important effect of climate change to consider now, taking into account that potentially negative consequences for yields due to increases in average temperature are projected to take place over several decades. Extreme weather events such as droughts and floods are also calling attention to the more immediate issue of water management, which is becoming an important issue in several countries in LAC.

As it was argued, the uncertainties about the path of GHG emissions and their impact on climate patterns may not be solved by the Fifth Assessment of the IPCC currently being conducted, considering that the more sophisticated GCMs utilized in this Assessment are likely to expand, rather than narrow, the range of potential climate change outcomes (Maslin M. and P. Austin, 2012).

Notwithstanding all the uncertainties mentioned, managing and adapting to those risks in LAC's agriculture merit special attention. The agricultural sector in the region needs to consider research and investments for adaptation to climate change in agriculture, such as the development of new varieties, using both biotechnology and conventional approaches, to enhance adaptation to highly variable conditions; different planting and/or harvesting dates; and shifting areas for production, considering

[99] Although it does not cover LAC countries, Reardon et al, (2012) show that for the rice and potato value chains in Bangladesh, China and India, energy costs are high along the supply chain: they may reach about 20% of the total costs in the postharvest segments of the rice value chain, plus there are other on-farm energy costs (including irrigation and machinery and equipment), which may add another 5%–10%. In potato chains in the countries analyzed, energy costs (particularly cold storage) can range from 13-23% of total costs. Reardon et al, 2012 conclude that "the importance of energy costs in transport, milling, cold storage, and farming in the rice and potato value chains of the three economies indicates that food prices are vulnerable to energy cost shocks. Consequently, energy costs in the food supply chain should be as important a food security debate topic as is farm productivity per se. Adding indirect use of energy (such as fuel and oil used in production of fertilizer as well as for pumping tube wells) strengthens this point."

changes in temperature, rain, daylight and the evolution of pests and diseases; and, in general, improve risk management systems. In particular, **e**xtreme weather events, particularly droughts and floods, demonstrate the urgent need for building resilience into production systems, including improved water management to achieve a more efficient use of the resource. Variable weather patterns require strengthening early warning and early response systems.

But agricultural R&D must include not only adaptation but also mitigation issues, considering that in LAC agriculture and land-use changes contribute to up to 2/3 of the GHG emissions against less than a 1/3 at the world level. Therefore, if the objective of maintaining GHG emissions on a path compatible with no more than a $2^{o}C$ temperature increase is to be achieved, and given agriculture's large direct and indirect contributions to GHG emissions in the region, then LAC's R&D must also deal with climate change mitigation, focusing on forests preservation, recovery of degraded pastures, use of minimum tillage approaches, development of other carbon sinks, sustainable livestock production, reduction of emissions in rice production, appropriate fertilizer use, and integrated management of pests and nutrients.

Both, as part of adaptation and mitigation, R&D on identification, sustainable use and conservation of biodiversity should also be a priority.

7.6 FOCUS ON "MULTIPLE WIN" TECHNOLOGIES.

The agricultural R&D topics selected by FORAGRO for GCARD I, are a valid general guide for R&D priorities in the region. In particular, biotechnology will be crucial to achieve better productivity levels, both for crops and livestock, helping increase the tolerance to biotic (pests and diseases) and abiotic (climate and soil) stresses. In addition, more efficient agronomic practices are needed for water management, improved zero tillage, integrated soil fertility management, integrated pest management, and reduction of post-harvest losses.

Also, as discussed, geo-referenced spatial datasets, and modeling approaches may help to make some of those priorities more operational. Still, all these methods, do not eliminate the problem that different technologies and production methods may differ not only in yields, but also a) in their impacts on the livelihood options for small farmers, the rural poor, women, and vulnerable populations, b) in the efficiency in using a variety of inputs, and c) in how they impact GHG emissions, local pollution, and biodiversity, among other things. At the same time, society is expecting from agriculture and food production to address more complex challenges involving the links between production and concerns about employment, poverty, food security, and environmental sustainability.

Therefore, any approach to decision-making regarding R&D in agriculture needs to consider technologies that generate "multiple wins." For instance, technologies can be graded considering several dimensions such as a) increases in yields and productivity in general; b) reduction in the use of material inputs (agrochemicals, water, and energy); c) support for family and small farms, while being gender and ethnically sensitive, and socially equitable; d) strengthening the resilience of farmers and vulnerable rural population in different climate change scenarios; and e) reducing GHG emissions from agriculture while increasing carbon storage on farmland, with adequate management of natural resources.

At the same time, other criteria such as scientific merits and programmatic concerns (including feasibility and readiness, and logistics and infrastructure), may have to be considered in agricultural R&D decisions (Popper et al, 2000).

In this regard, CIAT's "eco-efficiency" approach (CIAT, 2012) is a helpful way to assess technologies according to their ability to generate multiple wins. Further work is needed to develop metrics that takes into account such multiple criteria for deciding between R&D options.

7.7 SETTING PRIORITIES FOR R&D CANNOT FOLLOW JUST ONE APPROACH, AND "FORESIGHT" COVERS A VARIETY OF APPROACHES

Another point to be noted is that, as argued before, foresight exercises based on global scenarios, while helping with the broad outline of R&D strategies that would be robust across potential futures, may be too aggregate for the type of detailed decision making required at more operational levels. In this regard, what may be needed to identify the most promising technologies is the application of some of the more focused methods discussed in Section 3, such as Delphi surveys, Technological Road Mapping or Critical Technologies, and the use of new tools and concepts such as product life-cycle analysis, green value chains, and carbon footprint measurement, with approaches based on participatory research, dynamic knowledge sharing, and capacity building (CIAT, 2011).

Therefore, it seems important to maintain the diversity in foresight approaches and other strategic planning and methods of prioritizing technology decisions, some of which can be used at a world or regional scale, while others can be utilized for specific problems, areas, agricultural activities, and/or types of producers. Certainly, there is no single method that can address all the questions and issues than can help make adequate decisions about planning and implementation of agricultural technology activities.

7.8 WASTE REDUCTION AND AGRICULTURAL R&D

In previous sections food waste and the impact on food production and consumption was analyzed. The estimates tend to be around 30-40% (UK Foresight Report C7, 2011), but there are no many detailed studies across products and countries. A recent study by Reardon et al (2012), already referred to, found far smaller levels of waste in the rice and potato value chains in there South Asian countries. More analyses of this type are needed to ascertain the level of waste across food value chains, including perishable products such as fresh fruit and vegetables, dairy, meat and fish.

Still, it is reasonable to include waste reduction as one of the R&D priorities. As discussed before, the sources of waste and the place in the food chain differ significantly between developed and developing countries: in the first case, they occur more at the level of the final user (related in many cases to private sector standards and consumer's choices), while in the second case losses happen mostly between harvest and processing (usually because of lack of infrastructure) (see UK Foresight Report C8, 2011).

Of course, much of the waste to be avoided would come from private sector decisions (mainly in the food chain beyond the farm and closer to the final consumer) and/or public sector investments unrelated to agricultural R&D as such. Those non-R&D interventions may include infrastructure improvements (cold storage, transportation), better demand and weather forecasts, consumer education, and changes in standards (to avoid discarding edible food just because of external appearances). Although many of these interventions are not necessarily related to agricultural R&D as usually interpreted, there are different pre- and post-harvesting processes in which agricultural R&D may be relevant, including reducing the incidence of pests. A strong effort to reduce waste may then mitigate the imperative for R&D to increase production in the agricultural and food sector.

7.9 AGRICULTURAL R&D MUST FOLLOW CLOSELY CHANGES IN CONSUMERS' PREFERENCES.

A clear imperative from consumer's preferences is the need to produce healthy, safe, and high-quality food products. Agricultural R&D activities must incorporate those concerns. The development of standards should consider the possibility of small farmers to participate, the need to avoid waste, and the importance that sanitary standards converge in export and domestic markets.

Also, it was argued before that decision making about R&D priorities may need to use multiple criteria. Defining and using complex metrics to decide across R&D&I options is still a work in process. However, some of the components of that multi-criteria approach may be imposed in the end by the private sector following perceived consumer's preferences, such as carbon footprint, energy use, the impact on biodiversity, fair-trade approaches, and similar concerns. In this regard, it is important to place

increased emphasis on urban populations and consumer characteristics and preferences when deciding about agricultural R&D priorities. Consumers' desire for novelty can be addressed by developing little known species and varieties, now produced by traditional farmers and consumed in local markets; special R&D efforts can help create specialty markets for those products in which small farmers can participate.

The increased urbanization of LAC, and the fact that the number of the poor and food insecure is larger in urban centers, requires a more detailed consideration of urban food systems.

Different developing countries, including many in LAC, are experiencing the "double burden" of malnourishment, which is correlated with health issues both because of under-nutrition and over-nutrition, the latter leading to chronic diseases such as diabetes and high-blood pressure. An efficient way of improving health is to enhance the nutritional quality of the staple crops consumed by low-income populations. This will most likely require both non-GM and GM approaches. Those concerns must be acknowledged within agricultural R&D priorities, requiring a comprehensive consideration of the options involved.

Also, as discussed before, the evolution of meat consumption both in developed and developing countries, the impact of aging on food consumption in general, strong policy drives to reduce waste, and health concerns, in general, may change the level and composition of expected food demand. Scenarios such as Policy Reform and Global Change reflect those trends.

7.10 Continuous Adaptation and Improving Of The Institutional R&D Framework Is Crucial

Whatever the decisions about R&D priorities may be it is crucial to consider the institutional dimension: how to build capabilities in public and private organizations; how to establish successful cooperation and networks across public and private initiatives, including farmers, indigenous and rural communities possessing traditional knowledge, consumers, upstream and downstream agroindustries, and supermarkets and other outlets working directly with consumers; how to strengthen innovation transfer channels; and, crucially, how to finance all of the above.

As discussed before, the institutions for agricultural R&D in the region have evolved considerably, starting with the creation of public- sector national agricultural research institutes (NARIs or INIAs in Spanish) in the late 1950s, earlier than in other developing regions. Soon afterwards, three of CGIAR's international centers were established in LAC. Over time a regional institutional framework took shape, which included Cooperation Programs, such as the PROCIs; FORAGRO with IICA as its Secretariat; and various sub-regional structures. Within the public sector new actors (such as Universities) have emerged separate from the NARIs. Also, the private sector, including multinational companies, producer

associations, and NGOs have been expanding their activities in the development and diffusion of agricultural technology and, in many cases, the private sector has strongest capabilities than NARIs in modern techniques, such as those linked to genomics, engineering, and informatics.

Other important developments are changing the landscape where agricultural R&D institutions, specially public ones, must operate. One is related to the trend towards the convergence of life sciences (including those related to agriculture) with physics, chemistry, computer sciences, mathematics, and engineering, leading to the emergence of new interdisciplinary research areas, with important implications for agriculture and food security. As argued, these new research areas require significant capacity building and interdisciplinary integration in LAC, as well as institutional challenges. Supporting institutional innovation and expanding human capital and capabilities are particularly important, given that many researchers in LAC's public institutions are approaching retirement age.

Another change is that agriculture is expected to attend multiple demands, from increasing supply and alleviating poverty, to consider health and equity requirements, and environmental sustainability and climate change challenges. Those multiple expectations about agriculture also affect R&D institutions, which must go beyond a primary production focus to include the forward and backward linkages of the value chain, and to consider the views of a variety of social actors. .As it was noted before, private sector actors would follow market approaches based on private estimates of costs and benefits. The consideration and pricing of externalities and alternative societal objectives requires strengthening public policies, institutions, and investments related to agricultural R&D,

Finally, there is the realization that the problems affecting societies require to focus on innovation, which is a broader concept than R&D. Therefore, adjustments in R&D institutions must operate at three levels: first, the strengthening the individual NARIs; second, how those NARIs fit within the national system of R&D and technology transfer; and finally, how the first and second levels are integrated within the more general system of the national policies and institutions of the Innovation System (Trigo, 2012).

All these developments are profoundly changing the setting where NARIs must now operate, which then require important adjustments in their operations and financing, and need new organizational approaches, particularly to coordinate networks across multiple actors. Also, in many cases, individual countries in the region do not have the scale to undertake some of the R&D activities alone and there is therefore the need to expand regional and international networks. This is particularly important for the smaller and poorer countries in the region.

Finally a crucial issue is funding those activities, which includes two separate questions: what is the level of investments and what are the financing mechanisms (Trigo, 2012). Regarding the first issue it was already mentioned that R&D investments should at least be doubled, particularly in the smaller and poorer countries that are most in need of expanding agricultural R&D activities. These countries will also

benefit from beign integrated in regional and international networks. Regarding the second question, most of the funding is public and focuses on the NARIs. But it is necessary to innovate in funding mechanisms, which must ensure agile operational approaches and the integration of resources and capabilities from the institutions involved, including the private sector participation.

The scenarios discussed suggest a variety of challenges related to institutional issues. In low growth scenarios (such as Muddling Through and the Conflictive Regionalization), a problem would be to obtain adequate funding for R&D given the fiscal constraints, particularly in industrialized countries. This suggests the need for larger funding efforts on the part of developing countries.

Another aspect is the development of partnerships and networks. While in scenarios such as Policy Reform, Global Change, and perhaps in Collaborative Regionalization coordinated approaches are part of the potential futures, in others either there is no need for coordination because it is assumed that the market provides it (Market Optimism), it will be halting and weak (Muddling Through), it will not happen because of conflict (Conflictive Regionalization).

In summary, the current system will have to expand into coordinated national, regional and global systems and networks of innovation, including reformed NARIs, international organizations, universities, the private sector, consumers, and other stakeholders, which will require country investments of more than 1% of the agricultural GDP (the current average ratio of agricultural R&D intensity in LAC). In most of the scenarios, this will not happen spontaneously or will not happen at all, without conscious public policy decisions and investments.

7.11 FINAL COMMENTS

This review highlights the enormous challenges that lie ahead for agricultural R&D in LAC, involving issues of food security and poverty, and environmental sustainability in the face of climate change. Powerful socio-economic drivers could keep this region and the world on a business-as-usual path that may prove to be unsustainable. Reshaping those trends requires multiple interventions that go beyond the scope of agricultural R&D in LAC countries, from land distribution problems to solving global macro-economic imbalances and restoring world energy and climate balances. For all scenarios, however, higher levels of sustained investment in agricultural technology and innovation in LAC appear as a robust conclusion. Greater investment in LAC's agricultural and food production, including R&D, is vital for achieving food security and environmental sustainability – not just in this region but for the entire world.

As part of those efforts, and along with its responsibilities to other developing regions, the institutions involved in this exercise will continue to support the strengthening of a framework and process for foresight work in LAC that can help identify and develop appropriate agricultural technology

options that generate incomes and employment for family farms and the rural poor in that region, while fostering local, national, and global food security and sustainability. This document intends to be an input into that process.

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ANNEX 1. DIFFERENT APPROACHES TO FORESIGHT METHODS

1. Environmental Scanning This approach tries to identify important issues and new and emerging themes that conventional trend analysis, which requires compiled data, might not have identified yet. This technique can be done by passive, active and directing scanning of the environment. Passive scanning involves gathering information from magazines, newspapers, television, Internet sources, etc. Active scanning means to look at those sources with some criteria; and directed scanning implies organizing a selective approach with a defined goal. For examination of science and technology issues there may be bibliometric approaches that calculate the number of journal articles that are addressing some topics and/or patent analyses.
2. SWOT (strengths, weaknesses, opportunities, and threats) analysis This is a tool to identify internal and external factors that affect the performance of an institution. When SWOT applies to foresight, it focuses basically on future or emerging issues. SWOT analysis presents, usually in a 2 by 2 matrix, the strengths and weaknesses of the unit object of the study (from a country to an individual organization) considering its resources and capabilities, and a list of the threats and opportunities emerging in its environment. SWOT analysis is usually a dynamic tool, and is performed by experts groups that make an assessment on over several factors that affect the unit analyzed. Statistical analysis, benchmarking analysis, Delphi studies (see below) and other approaches are utilized to identify strengths, weaknesses, opportunities, and threats.
3. Issue Survey This type of surveys tries to identify important issues utilizing expert's opinions on certain topics. The group of experts is asked to answer, for example, which are the main drivers in the area considered, what types of problems and needs they create, what solutions may be required, what type of research or capabilities are required to achieve the solutions, and so on. The surveys may be utilized for Delphi studies, to gather background information on important developments, or for scenario development. This approach may reach a larger base of knowledge and engage people that may not be available for a longer process of consultation in foresight exercises.
4. Trend extrapolation This technique is one of the most used in forecasting. The method projects a future trend from historical data on a topic (for example population, GPD, other). Several statistical models are used to build these trends and a lot of insights are gained from their patterns. The main problem is how to take into account the forces that are affecting the trend and that may change its trajectory in a disruptive manner.
5. Simulation Modeling Computer simulation models are used to represent a system using what are considered its key components and relationships, and then simulate how a system can perform in the future under different assumptions about certain exogenous events (such as policy changes). This tool has advantages, such as working with a lot of variables simultaneously, requiring the collection of relevant data, facilitating the analysis of key components and links in a given system, forcing the expert group to think systematically about assumptions, and as well as about the starting conditions, interventions, and potential changes in the assumptions, and being able to present the results graphically. The disadvantages include the limitations in quantifying some key variables and relationships, and the complexity that may make very difficult for outsiders to understand the working of the model and verify data and assumptions.
6. "Genius" forecasting This term is used to illustrate the creation of a vision about the future from the opinion of an individual, who is a respected expert in that area. This individual provides insightful thoughts, perspectives and opinions about the future, sometimes out of the normal thinking process generated in a panel or a survey. The downside is that no person, whatever his or her level of knowledge and vision can cover the full range of elements and factors that may affect the future.
7. Delphi

This is a method based in structured surveys of opinion applied to a group of experts several times. It facilitates the gathering of quantitative and qualitative information, mainly used for long-term studies. In this technique, the experts can receive the survey at least two times, giving them feedback about the results after the first round. They are also allowed to change their answer during the process in order to promote the exchange of information and debate, and, because the survey is anonymous and the answers are summarized in a neutral way with equal weighting to all answers, it avoids the dominance of strong personalities or forcefully argued positions. Questions focus on issues such as when particular developments might happen (or alternatively how far a development might have occurred by a certain date), along with other questions about driving, facilitating and/or constraining factors, and about the socio-economic or other implications of those trends. They can provide important insights, but they require careful planning in terms of participants, questions, and feedback, and can be time-consuming and expensive.

8. Brainstorming

It is one of the better-known methods to generate new ideas and solutions to problems. It is used to produce original and creative ideas about a particular theme. Usually it has two steps: the first one is a period of free thinking, where ideas are presented without structure or criticism; in the second step, those ideas are organized into clusters, discussed more rigorously, and prioritized. Normally, brainstorming is just a starting point for a subsequent activity. In the case of future studies may be used to identify ideas about important trends, drivers, constraints, and disruptive events, all of which can be utilized for scenario building and/or for decision making.

9. Panel Expert

The panel provides an in-depth and free deliberation on a specific area of interest among a group of experts, which may vary in number, but usually comprises around 12 to 15 individuals. The panel creates an excellent environment for discussing an issue from different perspectives and academic backgrounds, using their judgment to interpret available evidence, detect lack of information, produce novel ideas, and identify new developments. The work should be based on clearly defined terms of reference. Panels can help in the networking of diverse groups.

10. Cross-impact analysis

This is a tool to produce quantitative results based on a specific statistical method for processing the data. It is mainly employed to create scenarios. A group of experts is asked about the likelihood of a set of events, including the likelihood when other of the events considered occur or not. This work generates a matrix with the interconnections and probabilities of occurrence of each event in different possible scenario, resulting to a combination of the events subject to mathematical analysis. The cross-impact method forces attention to chains of causality, being important to identify hidden interconnections and influence-dependency amongst variables. It allows the categorization of variables and drivers into different categories such as “Dominant drivers” (explanatory drivers which condition the system but do not depend on it); “Key drivers” (high influence and high dependency, and therefore unstable; they require careful consideration since they have strong linkages with other drivers); “Resultant or Dominated drivers” (influenced by other drivers but with low influence and medium to strong dependency); “Autonomous drivers” (trends or drivers relatively disconnected to the system); “Regulating drivers” (for which is difficult to state something in advance about their evolution) and “Neighboring drivers” (that are usually in the sidelines, but that may evolve into other categories, and therefore it is important to consider their evolution). It helps to determine whether a system is stable (a relatively low number of key variables or drivers with multiple interactions) or unstable. Cross impact analysis can be seen as an extension of methods like Delphi, which consider events independent of one another.

11. Scenarios

Some foresight studies use scenarios to develop a vision of the future (or several of them) and potential paths of development, all organized in a systematic way. Scenarios can be made by mathematical simulations, computer software, small groups of experts, or all of those approaches together. In this process of design and creation, the specialists need to identify the set of driving forces and its futures

trends, and the certainties and uncertainties about the issue behind analysis. They may be used as inputs to start a discussion on new ideas, as tools to present arguments, as a means of testing the robustness of policies, and/or as communication devices to interact with a wider public. There is a longer discussion of scenarios in the text.
12. Critical or key technologies These are approaches for assessing various technologies or research directions and define priorities during a foresight exercise. They are useful when discrete recommendations are needed for the decision-making process. They include key questions, for example what are the crucial areas of R&D, what are the critical technologies that define future research, what criteria should be applied to select the critical technologies, what are the most important policy measures that would enable the implementation of the results of that research, and other. Decision-making criteria on key technologies should consider some of the following aspects: first, their policy relevance (indicating potential policy interventions at different levels, such as processes of R&D, commercialization, diffusion and utilization); second, the criteria should be able to clearly discriminate between critical and non-critical technologies; finally, who likely is for the criteria to yield reproducible results. The method is based on four steps. First, the selection of the group of experts for consultation. Second, preparation of an initial list of potential technologies. Third, those technologies are classified in different groups and there is some prioritization through discussion and voting procedures. In this step the criteria for defining critical technologies is applied. Four, finalize the list of critical technologies, specifying their main characteristics, application areas and the critical problems to be addressed. This list then becomes a recommendation to policy-makers for budget and other policy decisions.
13. Technology road-mapping (TRM) This tool is applied to support technology strategic planning, particularly in the industrial sector. The road-map is a plan designed in several layers of time-based charts, with quantitative and qualitative information, linked with the market trends and driving forces that can affect the future development of the sector.
14. Analytical hierarchy process (AHP) This technique, also so-called "hierarchical networks," can be used to describe scenarios using indicators and probabilities of occurrence of each possible scenario. Different from other foresight techniques, it focuses on the behavior and decisions of multiple actors rather than on spontaneously occurring events. It focuses on actors that can influence the occurrence of the scenarios, and on their interests and behavior. This defines a hierarchical network model that allows the construction of scenarios with probabilities attached.
15. The Bayesian model This technique serves to understand which scenario will most probably become real from a given set of potential scenarios. The model is a strong tool to anticipate trends in a specific scenario and help the decision making process. The steps followed are usually the following: a) formulate the possible scenarios, which must be mutually exclusive and exhaustive (i.e. must cover the spectrum of all that could happen); b) assign "a priori" or initial probabilities for each scenario in relation to the information available at the time the exercise is initiated; c) register the events which start to occur and which constitute observable evidence; d) revise the probability estimates based on this new information; e) graph the evolution of the results to visualize tendencies.
16. Morphological analysis This technique is based on system analysis, which requires identification of the parameters and links of that system. In this tool, each parameter can adopt several possible forms, which will determine a different set of possible combinations and hence a potential morphological field. Within that potential field, a feasible morphological field is defined, in which the elements in their different characterizing parameters must be compatible.

Source: UNIDO, 2005

ANNEX 2. FORAGRO: PRIORITY AREAS, BOTTLENECKS AND PROCEDURES FOR THE AGRICULTURAL RESEARCH AND DEVELOPMENT.

Priority areas for agricultural research for development in LAC	Bottlenecks to solve / visions to promote	Procedures and partnerships needed
1. Increases in production and productivity. The region has a strategic contribution in terms of global food supply, which requires a significant boost in terms of new technologies. This must be addressed through: (i) renewed efforts on traditional crops- wheat, maize, rice, beans, potatoes, cassava, among others – having a high participation in the global food supply, as well as progressing on species underserved, particularly in tropical areas and sectors of small scale and family agriculture, and (ii) better utilization of existing productive land within the current agricultural frontier, so as to not only contribute to increased production, but also contribute to the protection of fragile ecosystems – particularly tropical forests.	Little use of technologies, particularly in regard to genetic improvement. Need to expand existing knowledge about soil management. Gap between average yields and potential. Lack of an integrated approach to value chain. Outdated Regulatory framework in strategic areas (intellectual property, biosafety). Structural or political factors preventing research to become innovation (difficulties in access to resources - land, finance - and markets, etc.) and innovation to turn into impact. Human resources without an adequate level of training.	Building on the successful experiences of cooperation in the region: PROCI's, disciplinary networks, growing networks (FLAR, CLAYUCA). Better integration between public and private sector at all levels (which is necessary to revise INIA's existing regulations for their relationship with the private sector and local governments). Promote mechanisms for the development of common visions among all stakeholders in the innovation system in specific territories or value chains.
2. Addressing the challenges of climate change Climate change will affect the productive environments of the region significantly, though not in the same direction in all cases, since, while some sub-regions will face new restrictions on their working conditions, others will benefit from changes in the parameters of temperature and water availability. These processes also offer new opportunities, particularly in regard to mitigation through the introduction of new technologies to reduce emissions in livestock	Poor availability of reliable information. Little development of scientific capabilities in relevant topics. The subject of climate change and its effects on agriculture and rural environments is little known and not incorporated into the design sectoral policies.	Improving interaction between communities and agricultural research related to climate change issues. Formalizing partnership and mechanisms for exchanging information and experiences among information generating centers and the various emerging administrative levels in the management of risks and effects of climate change. Ensuring –in the development of the mechanisms mentioned above– the incorporation of the experiences of indigenous communities in the management

or rice production, as well as carbon sequestration through the recovery of degraded pastures and application of minimum tillage techniques. In terms of specific priorities, the emphasis raises the need for adaptive responses to reduce vulnerability to short-term climatic events (year to year) through: (i) genetic improvements for enhanced crop adaptation to highly variable conditions, (ii) development of early warning and early response systems, (iii) generation of studies and information to improve risk management. As for medium-term adaptation, the development of more information about which will be the changes in the agro-ecological and productive scenarios (migration of pests and crops, prospective studies of changes in forms of production) as the basis for development of sectoral policies was identified.		of climate change. Articulating public-private networks to make progress in developing land management policies that recognize the principle of multi functionality in agriculture.
3. Diversification and differentiation of agricultural products and services The LAC region as a whole has very extensive productive and biodiversity resources, which are globally supporting a significant positive balance in terms of availability and diversity of the food to which its population has access. These opportunities may still be better exploited, not only from the standpoint of integration of the region in the markets, but also as a strategic source of income enhancement, and of improved social conditions of the inhabitants of the rural areas. For this, research should focus on (i) the development of technologies and innovations aimed at exploiting market "niches", (ii) the recovery of species and	Poor application of advanced technology (biotechnology) to biodiversity resources. Research agendas with little correspondence to the changes in domestic or export markets. The vision of "agribusiness" as opposed to family farming. Lack of a vision of innovative networks that integrate all stages from production to marketing.	Increased interaction between agricultural research institutes and agencies regulating markets and exports. Mechanisms for better coordination between producers and agribusinesses. Promotion of contract farming to facilitate access to new markets and lower the risk for small farmers.

varieties, now little used or used only by small farmers in local markets and (iii) the development of quality labels for small-scale agriculture as a source to support income generation and its better social sustainability		
4. Food Safety & Quality and access to food. Regardless of the aggregate performance of the region in global food markets, very different situations coexist within it, both in what regards to access to food (food security) and in terms of health and safety conditions of food being accessed by the populations of the region, particularly those with fewer resources. There is a need to go beyond production and food supply and consider access to food, domestic markets and urban food systems In this sense, the research priorities in terms of food security should aim at (i) ensuring sustained increases in staple food production, particularly those who depend on low-income sectors of the population, (ii) reduce losses due to the incidence of pests and post harvest handling and (iii) improving access to food for rural households through diversification of their sources of income for better utilization of productive resources at their disposal. (iv) put more emphasis on urban food systems and the related food transition with its impact on food security and health (particularly chronic diseases). As for food quality, it should be targeted a higher value-added food and ensuring their health and safety through the development of practices and monitoring and control standards allowing to establish sanitary	Vision of the "small-scale agriculture as part of the problem and not part of the solution." Artificial segmentation of markets (domestic and export). Lack of adequate regulatory frameworks and enforcement authorities with sufficient power and technical capacity to ensure compliance. Disarticulation between different institutional actors linked to the "quality" of food (Ministries of Economy, Health, Trade, Environment, Education and Agriculture). Too much focus on food supply than on access to food. Too few consideration of urban food system and food transition.	Incorporation of the family agriculture to food strategies. Strengthening of consumer organizations and promoting their participation in defining research agendas. Facilitate the direct linkage of business actors with producers and the establishments of special rules and arrangements for the training of all actors in the chain. Put more focus on urban food systems being used as an engine for agriculture in rural an urban areas. Multisectoral approach bringing together horticulture, health, education.

equivalence between the domestic and export markets.		
5. Development of agro-energy. LAC countries, with their high biodiversity and land availability, are some of the most important actors in the global markets of agro-energy, and these productions are already important priorities for several countries in the region (sugarcane, corn, soybeans, oil palm). However, there is clear potential conflict between these new opportunities and food production and social impacts into the rural sector, because of the potential expansion of large scale in these productions. To ensure the benefits of agroenergy to both the region and the global environment, research should be focused on (i) identification and technological development of new sources of raw materials that are not competitive with food production, (ii) progress in developing technologies for second and third generation and the use of lignocellulosic materials, and (iii) integrated production models which can incorporate a small-scale agriculture to agro-energy production, and integrate these new schemes in local development strategies	The concept of agro-energy as a large-scale process. Difficulties in the integration of agro-energy alternatives to national networks. In most countries there are no defined policies regarding the development of agro-energy alternatives. No coordination between different institutions working on the subject.	Promoting regional networks for collaboration and exchange of successful experiences (benchmarking). Involving farmers' associations in bioenergy projects. Promoting partnerships with other sectors of the energy field.
6. Conservation and sustainable management of natural resources The quality and relative availability of land, water and biodiversity resources are one of the main strengths of the region vis-à-vis many other regions of the planet, but negative experiences in the use of these resources also exist in the region. This highlights the future need for the availability of the skills needed to address these problems and ensure the conservation and	The poverty conditions and difficulties in access to land and how they lead to overexploitation of resources. The relatively low utilization of certain technologies such as integrated management of pests and nutrients as a result of restrictions on the production and distribution of appropriate inputs for their application. In some countries, lack of skills and human resources for the development of such	Mechanisms for dialogue and interaction between different disciplinary approaches and knowledge. Learn from successful experiences (watershed management, conservation technologies). Regulatory frameworks for the management of participatory resources (water, watersheds, biodiversity, soils). Partnerships between technological agencies and local

sustainable management of existing production potential. This requires research aimed at (i) the development of technologies to optimize the use of water and soil resources, including both specific issues such as the development of good practices, (ii) expand the use of environmentally friendly practices such as the integrated management of pests and nutrients, (iii) progressing in the sustainable use and conservation of biodiversity, including everything related to in-situ conservation, complemented by ex-situ, genetic improvement and strengthening of seed systems, and (vi) providing a scientific basis for production with an agro-ecological approach.	technologies. Lack of recognition of multifunctionality of agriculture. Institutional weaknesses that hamper access and water management.	governments. Mechanisms of productive zoning.
7. Promotion of institutional innovations The objective of development with social inclusion can only be achieved if there is an institutional framework that, on the one hand, promotes the generation of knowledge and technologies that effectively incorporate and synthesize the diverse needs and interests of different social actors, and, on the other hand, articulates the policy-making processes to transform such knowledge into innovation, improve productivity, inclusion and development. This involves generating knowledge and promoting institutional innovation processes (i) facilitate the integration of STI policies, agriculture, socio-economic and other, and concentrate on the promotion of innovation (rather than generation and dissemination); (ii) ensure the sustainable development of capabilities in new areas of knowledge and technologies; (iii)	Mistrust about the private sector does not allow taking advantage of opportunities to adequately address the development needs. Lack of prospective work that clearly identifies future demands. Little tradition regarding the use of participatory schemes. Innovation systems with little coordination among key players. Lack of spaces for the analysis and discussion of alternatives in terms of institutional organization and benchmarking successful processes of institutional innovation. Low levels of investment in R&D. Difficult change processes and institutional adaptation. Lack of incentives, i.e. fiscal incentives, and institutional frameworks. Research considers that delivering results always needs time, which is discouraging for the private sector and civil society organizations.	Institutionalization of FORAGRO as an area of discussion and promotion of institutional change. Put more emphasis on multidisciplinary research including social science and research on institutions, and interactions between stakeholders (Private sector, Civil Society, indigenous communities, women). Ready-to-use results and tool-kits.

considering the inclusion of family agriculture or small scale innovation systems; (iv) facilitate the development and operation of national and international networks, and other collective arrangements for R&D aimed at innovation; (v) provide for the strengthening of local, national and regional technological innovation, and their new interaction with the various existing international schemes, in general, and the CGIAR, in particular; and (vi) how to better involve the private sector and civil society as a key component for turning research into innovation and innovation into impact.		

ANNEX 3. A SUGGESTION OF KEY PRIORITIES FOR RESEARCH

1. PLANT & ANIMAL BREEDING AND GENETIC IMPROVEMENT

●● There is a strong correlation between investment in plant and animal breeding and resultant yields: further investment will achieve returns for all species – there is not convincing evidence that a yield or production ceiling has been reached, and the reservoir of natural variability in even intensively studied species has not been exhausted.

●● Investment in genomics and rapid phenotyping will provide the tools to enhance classical breeding using marker-assisted selection (a non-GM technique): major advances in yields, resilience (for example to drought and temperature extremes) and contributions to sustainability are possible using these methods in the medium term (2030) given sufficient investment.

●● Modern genomics simplifies the genetic improvement of less well characterized crop and livestock species, and there are particular breeding opportunities for those of relatively neglected but of importance in low-income countries.

●● Plant and crop breeding will be essential for agriculture to adapt to climate change and needs substantial public and private investment.

●● There are a number of radical suggestions for altering crop physiology, including the re-engineering of photosynthesis, the transfer of nitrogen fixation to grains, the introduction of apomixis and making annual crops perennial. These and related novel ideas are worthy of investment, although it is unlikely that they will be ready for deployment in the next decades (if ever). It is important to consider how they will be commercialized and distributed in real world markets.

●● Herbicide-resistant crops are some of the most widely planted GM varieties, but weed resistance is a threat, and progress is hampered by a lack of suitable herbicides.

●● The preservation of genetic material from crop varieties and livestock breeds, both common and rare, and from closely related species, is very important for future breeding and should be coordinated internationally.

●● Improved crop and livestock resistance to abiotic and biotic stresses can be achieved by classical and marker-assisted breeding capitalizing on huge improvement in our understanding of the basic biology, though many of the most ambitious projects (both in giving greater protection and being less susceptible to the evolution of resistance) require GM approaches.

●● There are major gains to be made from aligning disease research in medicine and veterinary science.

●● Improving the nutritional quality of the staple crops consumed in low-income countries is an important and cost-effective way of improving health, provided the seeds can be made available at prices affordable to poor people. Although some improvements can be made using non-GM breeding, there are others that cannot.

●● Research on engineering plants with suitable precursors, such that when they are fed to fish they are converted to omega-3 fatty acids, should be a priority because of its human health and environmental benefits.

●● Understanding the complex biology of ruminant microflora is important as it may lead to interventions that reduce the greenhouse gas emissions from livestock production.

2. CHEMICAL AND BIOLOGICAL RESEARCH

●● Some of the greatest negative externalities of agriculture arise from fertilizer production and use; scientific advances that provide even modest reductions in greenhouse gas emissions would make a large absolute contribution and are a priority.

●● Agrochemicals are critical to protecting crop yields throughout the world and will remain so for the foreseeable future. Major efforts must be made to reduce their direct and indirect environmental impacts,

but it is unrealistic to expect to produce enough food to meet demand by relying on nonchemical methods.
●● The search for pesticides, herbicides and fungicides with novel mechanisms of action is a high priority: basic research in structural chemistry and functional molecular biology, exploration of natural product chemistry, and further development of high-throughput screening are all important.
●● Further study of biological approaches to pest management, including inundative biological control, biopesticides, behavioral chemicals, genetic sterile insect technique (SIT,) and manipulating the microbial associates of crops and livestock, will provide novel control strategies, most with low environmental impact. Their greatest value is likely to be in specialist markets and for smallholder farmers. Issues of deployment under real agricultural settings are critical.
●● Pests that attack roots are a particular problem, and research on systemic pesticides, interactions between the root and the soil microbial community, and the biological response of the plant to root attack need particular attention.
●● Theoretical ideas about pest management using genetic drive are currently being considered to control the vectors of human disease; were these methods to succeed they should be adapted to control agricultural pests.
●● It will be important to protect and enhance biodiversity for raising production sustainably, for example by use of wild crop relatives, and biological pest control.

3. ENGINEERING AND TECHNOLOGY

●● Advances in engineering that will allow the more precise delivery of water and nutrients are important and will lead to economic and sustainable benefits in the relatively short term.
●● There are opportunities for novel hydroponic culture methods in areas where solar-powered desalinization is possible.
●● Advances in molecular diagnostics are making the rapid and routine surveillance for pests and diseases easier and cheaper; further investment in field-based techniques will have benefits both for reducing the burden of pests and disease and for their adaptive management with economic and environmental benefits.
●● The pace of change in ICT is so fast that it is hard to predict the technologies that will be available even a few years ahead; commitment to any one technology is unwise, and agility of response should be retained as much as possible.
●● Current advances in the ability to predict certain medium- to long-term weather patterns are likely to continue, and will be of most value to farmers in tropical countries, including the very poor; investment is required to overcome problems of disseminating timely information in an intelligible format.
From: UK Foresight (2011) Report C6.

ANNEX 4: DESCRIPTION OF SOME SCENARIOS

1. The Millennium Ecosystem Assessment Scenarios

Scenario Name	Scenario Description
SCENARIO 1: Global Orchestration	A globally connected society that focuses on global trade and economic liberalization and takes a reactive approach to ecosystem problems but that also takes strong steps to reduce poverty and inequality and to invest in public goods such as infrastructure and education. Economic growth in this scenario is the highest of the four scenarios, while it is assumed to have the lowest population in 2050. Global Orchestration is actually the scenario with the largest reduction of poverty and malnutrition. It is based on both the liberalization of trade and on major technological advances in terms of agricultural yields. The priority given to economic development in this scenario nevertheless results in a mainly reactive management of ecosystems and environmental problems.
SCENARIO 2: Techno-Garden	A globally connected world relying strongly on environmentally sound technology, using highly managed, often engineered, ecosystems to deliver ecosystem services, and taking a proactive approach to the management of ecosystems in an effort to avoid problems. Economic growth is relatively high and accelerates, while population in 2050 is in the midrange of the scenarios.
SCENARIO 3: Order from Strength	A regionalized and fragmented world, concerned with security and protection, emphasizing primarily regional markets, paying little attention to public goods, and taking a reactive approach to ecosystem problems. Economic growth rates are the lowest of the scenarios (particularly low in developing countries) and decrease with time, while population growth is the highest.
SCENARIO 4: Adapting Mosaic	Regional watershed-scale ecosystems are the focus of political and economic activity. Local institutions are strengthened and local ecosystem management strategies are common; societies develop a strongly proactive approach to the management of ecosystems. Economic growth rates are somewhat low initially but increase with time, and population in 2050 is nearly as high as in Order from Strength.

Source: Alcamo et al, 2005.

2. PROCISUR[100]

Scenario Name	Scenario Description
SCENARIO 1: NEO PARADIGM.	This scenario considers the strengthening of the synergy between the public and private organizations in order to increase the international integration and enhance the R&D and the ICT systems, by diversifying the technical and professional backgrounds. The technological innovation would increases productivity. The political dimension is characterized by institutional advances in ICT policies and new models of the agricultural research organization that improve the national systems. There is a sustained increase in the demand and supply of agricultural products and food; favored by agricultural policies on access markets and global trade liberalization. The environmental dimension is characterized by the diversification of production systems and species, based on market orientation and more research cooperation in renewable energy, carbon sequestration and assessment systems. From the socio-cultural dimension, it is characterized by greater inclusion of the family farming and its products, given by the application of a new approach of the R&D+I adapted to its needs.
SCENARIO 2: DELAYED FUTURE	There is an increased demand for R&D but still within the current paradigm. Internal research efforts are optimized, but without large investments, and the technology supply is increasingly occupied by transnational corporations. The lack of coordination and the poor convergence amongst the regulatory frameworks, create difficulties for further integration of the research systems at the regional level, which means that countries seek to expand on an individual basis. The production and economic sector have the same growth rates of demand and supply of food and raw materials to 2000-2007. The growth in food demand increase the production, product differentiation and processing. Also, there is an opportunity to position the region as a biofuels producer. There is a trade off in the land use for biofuels or food, and growing problems in legal framework for environmental regulations, aggravating the conservation of natural resources. There are no new employment benefits and they remain unfavorable for rural workers. Improvement in technology decreases the demand for labor and increase the qualification of the employees.
SCENARIO 3: EXTREME ENVIRONMENTALISM	In this scenario, the environment becomes priority. The Southern Cone loses strength as food supplier due the R+D+I turn to other priorities. It would be also a migration of professional competences outside the region. The national agricultural research systems fail to adjust their organizational models and institutional frameworks to meet a new context of ICT. The focus on social and environmental issues decreases the investment in agricultural technology, leading to the stagnation and reduction in the production levels. The low generation of local technologies and inputs increases the international dependence (fertilizers). This scenario focused on the social and environmental policies that have a positive impact on the inclusion of the excluded rural population; diversifying its sources of income and adding value to the production.
SCENARIO 4: INVISIBLE HAND	This scenario dismantles the regional and national scientific and technological systems and the R+D+I become dependent on the private investment and international funding agencies. The private sector becomes the protagonist in the management and execution of the agricultural research. The environmental aspect loses space against the consumer pressure, and competition for natural

[100] http://www.procisur.org.uy/index.php?option=com_content&view=article&id=609&Itemid=60

	resources increase.

Source: PROCISUR, 2010.

3. **Rabobank**

Scenario Name	Scenario Description
Scenario 1: Capricious Consent	This world is driven by primarily economic considerations. It is a multipolar world, which means that more than two economic powers – or countries – exert a major influence. Countries prefer to work together, because they realize that this is the best way to further their interests. Changes take place explosively and rapidly. Tensions are resolved in a harmonious manner and do not escalate into large-scale conflicts. In the heat of competition.
Scenario 2: Agil Antipoles	International tensions are running high. There are hotbeds of strife all over the world. Some of these concern ethnic or religious issues, but also the scarcity of natural resources is leading to conflict between countries and regions. Protectionism is the order of the day. The European Union has fallen apart, and the world lives in a continuous state of distrust, high alert and fear. Strict security measures are deemed essential. The gap between incomes is large, and because technological advancements are not being shared, there is fierce competition on the technological front. Business in chaos.
Scenario 3: Slow Strife	Slow Strife is a bipolar world. As in the last century, tensions abound between East and West. However, now it is China and the United States that oppose each other. International organizations such as the International Monetary Fund and the United Nations continue to be dominated by the West. The arms race has evolved into rivalry over economic sanctions and strongly protectionists measures. Regionalism has become the norm. It has become impossible to avert the energy crisis. There is an increasing shortage of food and clean drinking water, and the gap between rich and poor, as well as between the generations is widening. Amid interminable discussion, these opposing forces lead to long-term stalemate situations. Between a rock and a hard place.
Scenario 4: Flowingly Forward	This world is characterized by a strong commitment to improve the effectiveness of international organizations and to tackle cross-border issues in the area of energy and climate management and security. At the same time, decision making progresses slowly, because so many interested parties are involved. Consensus is sought on virtually all issues, which holds up the entire process of seeking solutions. Technological breakthroughs are few and far between and focus mainly on improving production processes. Business as usual.

Source: Piljic, D.; Stegeman, H. Rabobank, (2010).

4. Argentina

Scenario Name	Scenario Description
Scenario 1: My Way	This scenario includes: International Context: End of the financial crisis and lower corporate financialization; with a revitalizing U.S. in Latin America. International markets: Continuity of the WTO rules, with strong presence of the supermarkets; elimination of the trade restriction to export of grains; and a strengthening of the quality standards. R&D: Increase the importance of the European and American technological platform and continue process of quality improvement in science and technology. The agribusiness

	determines the R&D agenda; and INTA become an associated and subordinated part of the multinational corporations in agricultural technology. National Policy: The neo-development government ideas do not get consolidated in the country, and agri-liberalism resurges. Social-Technical Productive: high scale for biofuels production, expansion of the agricultural frontier but restricting the soybean monoculture; policies fail in encouraging alternative productions systems. Environment and Territory: Agribusiness leads the mitigation of the soybean monoculture effects over soil nutrients. Failures in territorial organization advances
Scenario 2: Up of the carousel spinning	This scenario includes: International Context: A systemic crisis defines the entire scenario and the regional integration between Argentina and Brazil does not work. International markets: Serious problems in food governance, with high fuel and food prices and strong market interventions, including regulations in the futures markets. R&D: The Asian technological platform does not get consolidated. The science and technology system becomes autonomous from national priorities; and the role of INTA is negatively affected by budget constraints and political uncertainties. National Policy: alternation between neo-development and liberal policies, leading to "stop and go" processes. Social-Technical Productive: The agriculture sector intensify its soybean monoculture, and an agri-finance logic controls the economy of the regions in the country, while the public assistance is still insufficient for those farmers who were displaced. Environment and Territory: Failed attempts to territorial organization; soybean expansion without restrictions seriously impacts on the environmental.
Scenario 3: The virtuous diagonal	This scenario includes: International Context: Finish to the crisis by G-20, Argentina and Brazil strengthening its alliance due a potential threat from the Chinese crisis; the US tries to recreate a simile Alliance for Progress in Latin America. International markets: Sustained process of wealth accumulation and growth of the emerging regions; market opening for products with value added; improvement of the food supply due to increases in production from Africa and Eastern Europe. R&D: The consolidation of the Asian technological platforms challenges the dominance of Euroamerican ones; continuing improvement in agricultural innovation. The science and technology (S&T) system plays a core role in supporting agribusiness; adapting technology to local producers and regional economies; synergies with S&T from Brazil by strengthening the alliance EMBRAPA-INTA. National Policy: Consolidation of a new model of neo developmentalist and new national actors in Argentina's agrifood and agroindustrial system; a national agreement in the agricultural sector improves the quality of policy making. Social-Technical Productive: Increased importance of the agricultural sector for the Argentine economy; creation of integrated poles of agricultural-livestock- and energy in regional economies; a new basis for an alternative paradigm. Environment and Territory: Stabilization of the agricultural frontier and land tenure; preservation of natural resources and the recognition of the identity of the indigenous peoples are part of the public agenda.
Scenario 4: ArgenChina	This scenario includes: International Context: The global crisis ends thanks to China; Latin-American integration is compromised. International markets: China expands around the world significantly, and the emergent

	economies become more specialized as primary producers. R&D: China uses technological dumping, and creates satellite platforms with the logic of a food deficit country. INTA's Agenda is contingent on the needs of China; and the alternating policies and projects diminish the effectiveness and consistency of INTA. National Policy: The Neo-developmentalist model is truncated and alternated with the agri liberalism. Problems of governance in the provinces. Social-Technical Productive: There is a reduction of products with value added processes; China invests in extractive industries and food production; China copies Argentina's agro technological models; and the labor force is affected in the peripheral regional economies of the country. Environment and Territory: Exacerbated socio-environmental conflicts; worsening governance over the territory and natural resources; expansion of soybean production.

Source: Patrouilleau, R. D. INTA, (2012).

5. Chile

Scenario Name	Scenario Description
Scenario 1: Business as Usual (BAU)	In the BAU scenario the future opportunities and challenges are perceived to be in further integration of Chile's agriculture in international and domestic markets. The consensus is that a strong "**Chile brand**" needs to be developed, based on excellent compliance with market norms and standards, and supported by a labor force that is able to understand and implement such compliance mechanisms[101]. The main aspects of this scenario are: a good competitive positioning; product and market differentiation; entrepreneurs and more sophisticated labor force; and high value and differentiated products. Other specific variables are : **a) Few climate variations (on average temperatures and rainfall regimes have remained the same), and there is not effect over the natural resources.** **Science and Technology**: Molecular biosciences (biotechnology, genomics and proteomics) have become the main drivers of biological sciences and are increasingly applied to environmental, pharmaceutical and varietal improvement research**.** ICT is widely used in the agro-food and forestry sector and their production chains both at the local and international level. Traceability and precision farming systems are common and have become indispensable for accessing consumers markets that are increasingly concerned with where and how their food has been produced. **b) High increase in demand of meats and fruits.** By 2030, the global area dedicated to agriculture has been increased with 121 million new hectares. The developing countries' middle class has tripled in size and adopted consumption patterns that favor meat, fruits and vegetables, becoming the most important target group for Chile's export agriculture. Consumers from the EU and the US have opted for a return to locally grown products. In general consumers appreciate to know that their food has been produced in ecologically balanced and sustainable systems. **c) No change in tariffs.** **d) Regulations over use of natural resources**
Scenario 2: Terra Calida	In the Terra Calida scenario, the logic changes. Chile's agricultural sector might still wish to be a bigger player in the international and domestic markets, but if it is not able to successfully adapt to the changed climatic conditions, market success will be difficult. The main aspects of this scenario are: managing production conditions is the key challenge;

[101] Page 19. Chile 2030 Vision. 2011.

	Chile should further increase its investments in the innovation system; priority should be given to the production and marketing of environmentally sustainable products, for which it is needed to have highly educated staff with multidisciplinary resource management skills, and competitive, resource-efficient value chains. Other specific variables are : a) Temperature increases and precipitation rate is lower b) Limited increase in demand because of higher prices c) Tariffs on carbon footprint d) More regulations over use of natural resources
Scenario 3: Liberal BAU	This scenario is similar to Scenario 1 but with less market intervention. Other specific variables are : a) Few climate variations b) High increase in demand of meats and fruits. c) No change in tariffs. d) Few regulations over use of natural resources
Scenario 4:	This scenario focuses in low policies intervention and high impact on climate change. Other specific variables are : a) Price increase of oil and fertilizers b) Increase in quality requirements c) Biotechnology development, ICTs

Source: FIA. (2011).

6. The Great Transition (Global Scenario Group; GSG)

Scenario Worldview	Scenarios	Anteceden	Philosophy	Motto
Conventional Worlds: Assume the global system in the twenty first century evolves without major surprise, sharp discontinuity, or fundamental transformation in the basis of human civilization. The dominant forces and values currently driving globalization shape the	Market Forces	Smith	Market optimism; hidden and enlightened hand. Competitive, open and integrated global markets drive world development. Social and environmental concerns are secondary.	Don't worry, be happy

future. Incremental market and policy adjustments are able to cope with social, economic and environmental problems as they arise.	Policy Reform	Keynes Brundtland	Policy stewardship. Assumes that comprehensive and coordinated government action is initiated for poverty reduction and environmental sustainability	Growth, environment, equity through better technology and management
Barbarization Barbarization foresees the possibilities that these problems are not managed. Instead, they cascade into self-amplifying crises that overwhelm the coping capacity of conventional institutions. Civilization descends into anarchy or tyranny	Breakdown	Malthus	Existential gloom; population/resource catastrophe. Conflict and crises spiral out of control and institutions collapse.	The end is coming
	Fortress World	Hobbes	Social chaos; nasty nature of man. Features an authoritarian response to the threat of breakdown, as the world divides into a kind of global apartheid with the elite in interconnected, protected enclaves and an impoverished majority outside.	Order through strong leaders
Great Transitions. Great Transitions, the focus of this essay, envision profound historical transformations in the fundamental values and organizing principles of society. New values and development paradigms ascend that emphasize the quality of life and material sufficiency, human solidarity and global equity, and affinity with nature and environmental	Eco-communalism	Morris and social utopians Ghandhi	Pastoral romance; human goodness; evil of industrialism. Eco-communalism is a vision of bio-regionalism, localism, face-to-face democracy and economic autarky. While popular among some environmental and anarchistic subcultures, it is difficult to visualize a plausible path from the globalizing trends of today to Eco-communalism, that does not pass through some form of Barbarization.	Small is beautiful

sustainability	New Sustainability Paradigm	Mill	Sustainability as progressive global social evolution. This scenario changes the character of global civilization rather than retreat into localism. It validates global solidarity, cultural cross-fertilization and economic connectedness while seeking a liberating, humanistic and ecological transition.	Human solidarity, new values, the art of living

Source: Raskin, et al (2002).

7. Brazil

Scenario Name	Scenario Description
Scenario 1: Integrated Expansion with Global Insertion	The world shows a favorable process of integration (international axis) and the domestic environment in Brazil for the National System of Agricultural Research (SNPA in Portuguese) and related agricultural activities is positive (national axis). The SNPA experiences a process of integrated expansion and strengthening, with increasing insertion in global networks of R&D&I and of agribusiness, contributing to the sustainable use of biodiversity, stimulating the dissemination of technological innovation, and the existence of high value added in the Brazilian agribusiness.
Scenario 2: Integrated Expansion with Regional Insertion	The world shows an unfavorable process of integration (international axis) but the domestic environment in Brazil for the National System of Agricultural Research (SNPA in Portuguese) and related agricultural activities is positive (national axis). In spite of unfavorable international conditions, which limit the external insertion, the SNPA experiences a gradual process of expansion and strengthening, contributing to a greater sustainability in the use of natural resources, stimulating the dissemination of technological innovation, and greater value added in agribusiness in Brazil.
Scenario 3: Sectoral Expansion with Niche Insertion	The world shows a favorable process of integration (international axis) but the domestic environment in Brazil for the National System of Agricultural Research (SNPA in Portuguese) and related agricultural activities is not positive (national axis). The SNPA cannot take full advantage of the favorable external context and experiences a process of expansion limited to some specific segments, with global insertion restricted to products with globally competitive value chains, addition to value added concentrated in some niches of agribusiness, and low sustainability in the use of biodiversity.
Scenario 4: Disarticulation and Regress	The world shows an unfavorable process of integration (international axis) but the domestic environment in Brazil for the National System of Agricultural Research (SNPA in Portuguese) and related agricultural activities is not positive (national axis). The limitations generated by the unfavorable macro-context, marked by limited aggregation of value and predatory use of biodiversity, are exacerbated internally by the increasing weakening and disarticulation of the SNPA, which presents a limited insertion in some niches of the national and regional markets.

Source: RIPA, 2007